Policy Research

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World Development Report

WPS 979

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Background paper for World Development Report 1992

Economic Growth and the Environment

Dennis Anderson

Addressing environmental problems efficiently should be viewed as a means of raising economic growth and living standards in developing countries, not of reducing them — contrary to the standard historical and contemporary view in industrial countries.

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This paper — a product of the Office of the Vice President, Development Economics — is one in a series of background papers prepared for the *World Development Report 1992*. The *Report*, on development and the environment, discusses the possible effects of the expected dramatic growth in the world's population, industrial output, use of energy, and demand for food. Copies of this and other *World Development Report* background papers are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact the *World Development Report* office, room T7-101, extension 31393 (September 1992, 80 pages).

Anderson argues that efficient solutions to environmental problems are a means of improving a country's economic growth prospects and that policies to improve economic growth prospects will help environmental problems be addressed. Among other points he makes:

• The costs of avoiding pollution or environmental damage are often less than the costs of incurring it. The costs of incurring such damage take many forms, including the impact of air and water pollution on health and amenities, the loss of time and output caused by urban congestion, the health implications of hazardous wastes and poor waste treatment and disposal practices, and the decline in productivity of soils and forests that results from unsustainable agricultural and forestry practices.

• With exceptions, environmental problems cannot be addressed by market forces alone. In some instances, the costs of environmental damage may be borne wholly or partly by agents other than those responsible for the damage. Some sort of tax, law, regulation, or framework for negotiation will be required to bring about a convergence of private and social interests in reducing damage in an economically desirable way.

• When policies are not in place, economic growth may intensify environmental damage and eventually be retarded by it. By contrast, when the right policies are in place, not only may such damage (and its impact on growth) be reduced to low levels, but economic growth may help to achieve environmental improvements — through, for example, raising the finance for water and sanitation facilities or for the maintenance of forest and wildlife reserves.

• The most effective way to reduce environmental damage from economic activities and their expansion is to address it directly — to "delink" it from economic activities, so to speak — by introducing environmentally superior technologies and practices.

• Reducing population growth would help relieve environmental pressures in urban and rural areas, but these effects would be small in relation to two other measures: reducing waste and inefficiency and introducing environmentally superior technologies and practices.

• For the most part, environmental policies succeed because of certain behavioral responses they may cause — in particular, a range of substitutions and technological and managerial changes that give rise to environmentally inoffensive practices.

• The evidence that pollution has a disproportionately higher impact on low-income groups is overwhelming.

<u>Economic Growth and the Environment</u>

Dennis Anderson

Background Paper Prepared for the
<u>World Development Report 1992</u>

The World Development Report 1992, "Development and the Environment," discusses the possible effects of the expected dramatic growth in the world's population, industrial output, use of energy, and demand for food. Under current practices, the result could be appalling environmental conditions in both urban and rural areas. The World Development Report presents an alternative, albeit more difficult, path - one that if taken, would allow future generations to witness improved environmental conditions accompanied by rapid economic development and the virtual eradication of widespread poverty. Choosing this path will require that both industrial and developing countries seize the current moment of opportunity to reform policies, institutions, and aid programs. A two-fold strategy is required.

• First, take advantage of the positive links between economic efficiency, income growth, and protection of the environment. This calls for accelerating programs for reducing poverty, removing distortions that encourage the economically inefficient and environmentally damaging use of natural resources, clarifying property rights, expanding programs for education (especially for girls), family planning services, sanitation and clean water, and agricultural extension, credit and research.

• Second, break the negative links between economic activity and the environment. Certain targeted measures, described in the Report, can bring dramatic improvements in environmental quality at modest cost in investment and economic efficiency. To implement them will require overcoming the power of vested interests, building strong institutions, improving knowledge, encouraging participatory decisionmaking, and building a partnership of cooperation between industrial and developing countries.

Other World Development Report background papers in the Policy Research Working Paper series include:

Dennis Anderson, "Economic Growth and the Environment"

Dennis Anderson and William Cavendish, "Efficiency and Substitution in Pollution Abatement: Simulation Studies in Three Sectors"

William Ascher, "Coping with the Disappointing Rates of Return of Development Projects with Environmental Aspects"

Edward B. Barbier and Joanne C. Burgess, "Agricultural Pricing and Environmental Degradation"

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Wilfred Beckerman, "Economic Development and the Environment: Conflict or Complementarity?"

Richard E. Bilsborrow, "Rural Poverty, Migration, and the Environment in Developing Countries: Three Case Studies"

Charles R. Blitzer, R.S. Eckaus, Supriya Lahiri, and Alexander Meeraus,
(a) "Growth and Welfare Losses from Carbon Emission Restrictions: A General Equilibrium Analysis for Egypt";
(b) "The Effects of Restrictions of Carbon Dixide and Methane Emissions on the Indian Economy"

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Robert E.B. Lucas, David Wheeler, and Hemamala Hettige, "Economic Development, Environmental Regulation and the International Migration of Toxic Industrial Pollution: 1960-1988"

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Stephen Mink, "Poverty, Population and the Environment"

Theodore Panayotou, "Policy Options for Controlling Urban and Industrial Pollution"

Other (unpublished) papers in the series are available direct from the World Development Report Office, room T7-101, extension 31393. For a complete list of titles, consult pages 182-3 of the World Development Report. The World Development Report was prepared by a team led by Andrew Steer; the background papers were edited by Will Wade-Gery.

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INTRODUCTION

Economic growth is essential if living standards in developing countries are to increase, and if chronic poverty, which currently afflicts more than one fifth of the world's population, is to be overcome. This paper argues that efficient solutions to environmental problems are a means of improving a country's economic growth prospects; and conversely, that policies which improve economic growth prospects will help environmental problems to be addressed.[1]

This argument is made first in general terms, and then more specifically for a range of different environmental problems: potable water and sanitation, energy issues, global warming, industrial pollution, and agricultural concerns. These various sections contain numerous boxes, detailing empirical cases that bear on the issues in question. In conclusion, some common threads are discussed under four headings: the growth of populations and per capita incomes; the links between poverty, growth and the environment; the environmental importance of economic stability and trade; and the environmental importance of the efficiency with which resources are used. The aim is to show, by reference to actual situations, and to known practices and technologies, how economies may -- and, historically, often have -- improved their environments in the course of economic growth and development, and conversely, their economic growth and development prospects in the course of improving their environments.

I. THE ARGUMENT IN GENERAL TERMS

This can be made by reference to five aspects of the inter-relationship between economic growth and the environment: first, the relative costs of environmental damage; second, the key role of environmental policies; third, tradeoffs; fourth, technological and managerial responses to policies; and fifth, macroeconomic enabling conditions for successful environmental policies.

1. Relative costs

One of the most significant lessons from past environmental policymaking experience is that the costs of avoiding pollution or environmental damage are frequently less than those of incurring it. The costs of incurring such damage take many forms including, as discussed below, the impact of air and water pollution on health and amenities, the loss of time and output caused by urban congestion, the health implications of hazardous wastes and poor waste treatment and disposal practices, and the decline in productivity of soils and forests that results from unsustainable agricultural and forestry practices.

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[1] These themes are not original, and are to be found in several studies of environment and development, for example in the Brundtland Report, Our Common Future.

Hence, addressing environmental problems efficiently should be seen as a means of raising economic growth and living standards in developing countries, and not of reducing them; this is contrary to the standard historical and contemporary view in the industrial countries.

2. The role of environmental policy

The general relationship between economic growth and the environment turns crucially on the nature of environmental policy. Within broad limits, economic growth may follow either environmentally desirable or environmentally damaging paths; the difference between the two is an outcome of the social choices people and their governments and industries are willing and able to make.

With exceptions, environmental problems cannot be addressed by market forces alone. In some instances, the costs of environmental damage may be borne wholly or partly by agents other than those responsible for the damage, and some sort of tax, law, regulation or framework for negotiation will be required to bring about a convergence of private and social interests in reducing damage in an economically desirable way. Public expenditures may be directly required in some cases, such as the protection of forest and wildlife reserves, or the development of new, low polluting energy technologies such as renewables. In others, there may be property rights issues; both public (as with national parks), and private (in agricultural and urban areas).

These policies may have a bearing on economic growth and the physical environment. It is argued below that when policies are not in place, then, as many have argued, economic growth may intensify environmental damage and eventually be retarded by it. In contrast, when the right policies are in place, then not only may such damage (and its impact or growth) be reduced to low levels, but economic growth may help to achieve environmental improvements -- through, for example, raising the finance for water and sanitation facilities or for the maintenance of forest and wildlife reserves. The following figure summarizes the general linkages and the key role of policy:

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  ┌────────────────────────→ Economic Growth ←─────────────────────┐
  │                            ↙            ↘                      │
  │              Environmental              Environmental          │
  │              policies not in place      policies in Place      │
  │                                                                │
lowers output                                                raises output
and growth              ↓                        ↓           and growth
  ↑              Environmental              Environmental          ↑
  └──────────────damage extensive           damage avoided─────────┘
                 (intensified by            (damage avoidance
                  growth)                    helped by growth)
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3. Trade-offs

Environmentally-related expenditures frequently have good economic rates of return once their external benefits are taken into account. Tradeoffs between economic growth and the environment are generally encountered in two circumstances: (i) at the margins of policy, when environmental standards are already high, and the costs of achieving further improvements rise steeply in relation to benefits; and (ii) when environmental damage and resultant implications for human welfare only take effect over the longer-term. (Commonly cited examples of the latter include the disposal of hazardous wastes, global warming, and the "mining" and clearance of forest and wildlife reserves.)

Despite these potential trade-offs, many circumstances provide support for environmentally desirable projects and investments, since the starting point for policy is generally not one where environmental standards are close to the margin but where they have yet to be defined. Indeed, there are numerous instances in which the standards are negative, in the sense that environmental damage is being subsidized or otherwise encouraged, and not taxed or regulated as efficient policies require. In these cases good economic and environmental policies may be thrice blessed, yielding an economic improvement from the removal of unnecessary subsidies, a further economic improvement from the reduction of external costs, and environmental improvements.[2]

Moreover, although the costs of environmental damage are often long term, preventive expenditures are often justifiable on economic grounds. All civilized societies sacrifice current consumption (and many people, their lives) in the interests of future generations, investments in education being only one of many examples. Like investments in education, investments in avoiding long-term environmental damage often have good economic rates of return. This case is developed further below by reference to global warming (where energy efficiency and renewable energy technologies are shown to have considerable economic promise), to hazardous wastes (where the costs of waste reduction and safe disposal are less than the costs of clean up), and to tropical forests and wildlife (where these are valued as a public good as well as for the economic value of biodiversity).

4. Responses to policy

For the most part, environmental policies succeed because of certain behavioral responses they may cause, and in particular a range of substitutions and technological and managerial changes that give rise to environmentally inoffensive practices. When an environmental measure of some kind (a law, a regulation, a private settlement between polluting and polluted parties, an environmental tax or user charge, etc.) is introduced, <u>two</u> effects must be considered (see Box 1). The <u>first</u> raises the costs of the activity in question, and thus the price of its products and services. This then reduces demand and supply in accordance with prevailing price elasticities. With unchanged practices, this reduction will lessen environmental damage -- though the effect is generally small. For instance, a 20 percent cost increase arising from a regulation or a tax may typically reduce pollution (with unchanged practices) by 10 to 20 percent; this small effect would soon be over-ridden by three or four years' normal growth of the activity in question.

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[2] Reference to papers by Repetto and Warford.

The second and far more important effect, is to encourage more environmentally-benign practices. In nearly all reported cases, alternative products, substitutes or methods of production, which would reduce the damage from an environmentally offending activity to low or negligible levels, are either available, emerging, or capable of development. Table 1 lists examples from the major problem areas discussed below -- water and sanitation, local and regional pollution arising from energy production and use, global warming, industrial emissions and wastes, and soil erosion. The right hand column shows the rate of damage from a low-damage alternative (using proven technologies or practices) as a percentage of the rate of damage from those current practices still in use in many regions. This indicates that some substitute or technological or managerial alternative exists which is capable of reducing damage by factors ranging from 10 to 1,000, sometimes higher. The implication is that, once environmentally sound policies are in place, output can expand and damage can be appreciably reduced.

Another feature of the response to environmental problems, once policies are in place, is innovation -- in clean coal technologies, in the production and use of natural gas, in refining and the use of emissions control devices for transport fuels, in the treatment of human and industrial wastes, and in the possibilities developed over several centuries for the sustainable management of soils, forests and natural resources. The effects of such innovations are twofold: first, to lower the costs of compliance with policy (see Table 2); and second, to improve effectiveness (for example, though reduced emissions per unit of output). These developments have left developing countries much better placed to address environmental problems than were the industrial countries at a comparable stage of development.

However, while adopting environmentally improved practices may allow the "delinking" of environmental concerns from economic growth, the time required to incorporate these practices into an economic system may nevertheless be appreciable even after a policy is agreed upon, itself a disputative and time consuming process. In the energy and manufacturing industries, the operating lifetimes of investments already in place are typically twenty to thirty years; even where retrofitting is possible, it may take two or three decades to change from polluting to low-polluting capital stock. Transforming management practices in agriculture and forestry may take even longer. For these reasons it seems certain, even under an optimistic scenario, that environmental problems will intensify in developing countries - as they did in the industrial countries - before they can be ameliorated.

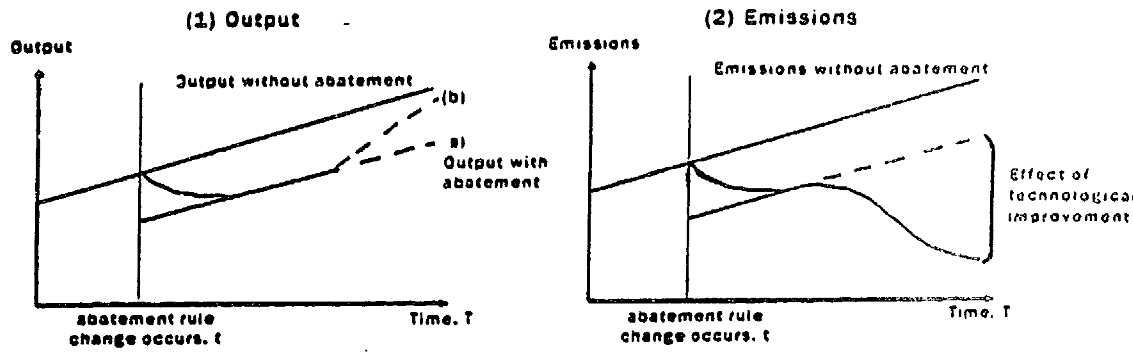
5. The macro-economic enabling conditions.

Macro-economic stability not only provides a sound basis for economic growth, but also for successful environmental policy-making.[3] This is for several reasons.[4]

[3] Stability is defined as the avoidance of rapid inflation and large swings in output and employment opportunities; the reduction of unsustainable debt burdens; and, related to the foregoing, the maintenance of satisfactory fiscal, monetary and external balances.

Box 1

SCHEMATIC REPRESENTATION OF POLLUTION ABATEMENT ON:



Notes: The figures consider an expanding industry with and without abatement policies. If taxes or quantitative restrictions are introduced, higher costs and prices reduce overall demands and supplies (depending on elasticities) and there is also a quantitative drop in pollution on account of reduced activity. However, the quantitative effects of output reductions on pollution, in the absence of new abatement practices being introduced, are quite small--and are soon offset by further expansion of the industry. The decisive effect on pollution comes when new, low pollution technologies or substitutes are developed and are gradually introduced into the capital stock, either as integral features of new plant (such as gas-fired power stations) or as add-on technologies to existing plant. This technological response takes more time, but in numerous cases may eliminate the pollution almost completely even while the industry expands.

Despite the simplicity of the model, it is widely applicable. The following are examples discussed in the text:

- Emission control and clean fuel technologies for electricity generation and transport;
- Renewable energy and CO_2 emissions;
- Potable water and sanitation;
- Pollution from domestic heating;
- Industrial pollution prevention and abatement;
- Agriculture and soils;

There are, in some cases, even surprises in which the clean technologies and practices, once developed, may become less costly. Natural gas and clean coal technologies for power generation are some possibilities; agroforestry and its impact on soil fertility is another. Hence, once incorporated in the capital stock, costs may in fact decline and output rise in relation to the historical trend (case (b) in the upper figure).

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[4] Killick (1991).

Table 1 Relative pollution (or damage) intensities of pollution or low polluting practices

Source	Basis of index of damage [a]	Practice		Nature of Alternatives
		Polluting	Nonpolluting	
Particulate matter	Emissions	100	<0.1	Natural gas; clean coal technologies; scrubbers; low sulphur fuels
CO	"	100	<0.1	
SO_2	"	100	0 to <5	
NO_x	"	100	5 to <10	
CO_2	"	100	0	Renewables
Pb	"	100	<0.1	Unleaded fuels, New Octane enhancers; catalytic converters
VOCs	"	100	<2	
Marine pollution (oil)	Spills and waste	100	<10	
Surface water pollution	Volume of waste	100	<1?	Sewerage works; Effluent control technologies;
Soil erosion[b]	Soil loss	100	negligible	Agro-forestry; soil erosion prevention practices (contouring, terracing, mulching, vetiver grasses, and others).
Forestry	Areas cleared in damaging ways.	100	negligible	'Sustainable' practices as compared with uncontrolled logging and land clearance.
Industrial effluents and wastes[e]	Emissions and wastes (by weight and volume)	100	small[e]	Effluent control technologies (water and air); waste reduction or 'prevention' through substitutes; in-plant recycling; product recycling.'

a. Per unit of output
b. Irrigation and salination to be added.

deficient water supply and sanitation services pose perhaps the most serious current environmental problem in developing countries, as they did historically in the industrial countries.

Consider first the consequences for health. There are five categories of disease related to poor sanitation and water supplies[5]: (a) water borne diseases such as typhoid, cholera, dysentery, gastro-enteritis and infectious hepatitis; (b) water washed infections of the skin and eyes such as trachoma, scabies, yaws, leprosy, conjunctivitis, and ulcers; (c) water-based diseases such as schistosomiasis and guinea-worm; (d) diseases from water-related insect vectors (mosquitoes and blackflies); and (e) infections that are primarily caused because of defective sanitation and poverty, such as hook-worm.

Immense numbers suffer from water-related diseases. The World Health Organization (WHO) estimates that 750 million children contract acute diarrhoeal diseases annually; these diseases are associated with 4 million deaths under the age of 5 each year, due mainly to the dehydration of their victims.[6] It is also estimated that at any one time there are probably 500 million people with trachoma, 250 million with elephantiasis, 200 million with schistosomiasis or bilharzia, 160 million with malaria, 100 million with diarrhoea, 800 million with hookworm, and 20 million with onchocerciasis (river blindness).[7] The number of people afflicted by the infectious diseases of cholera, typhoid and paratyphoid varies greatly annually, with epidemics an incessant threat given that water and sanitation systems (in combination with an inadequate understanding of the importance of hygiene) fail to provide for the basic needs of such large numbers.

Improvements in water and sanitation may substantially reduce the incidence and - a less commonly recorded figure - the severity of these diseases. A USAID review of 144 studies found that with improved access to water and sanitation, reductions in mortality from diarrheal diseases averaged 22 percent (morbidity 65 percent), ascariasis 28 percent, guinea worm 76 percent, schistosomiasis 73 percent, trachoma 50 percent and hookworm 4 percent.[8] Reductions in child mortality averaged 60 percent. The apparently low impact on hookworm is the

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[5] The following is extracted from the United Nations Report on the State of the Environment (19).

[6] World Health Statistics (1989). WHO Geneva

[7] UN State of the Environment, op.cit, and US Aid Technical Report No. 66, July 1990 "Health Benefits from Improvements in Water Supply and Sanitation: A Survey of the Literature on Selected Diseases."

[8] USAID (1990) "Health Benefits ..." op.cit.

Table 2 Costs of Low Polluting or Damaging Practices in Relation to Total Costs

Source of pollution or damage	Costs of non-polluting or damaging practice
PM - Coal Power Stations	1% of capital costs
SO_2- Coal Power Stations	20% of capital costs with retrofitting; 10% of capital costs on new plant; 0% or negative with low sulphur fuels and emerging clean coal/high efficiency technologies
CO_2-Electricity generation	Near-term: 50-100% higher than fossil fuels Long-term: costs are comparable to fossil fuels (Estimates based on renewable energy)
Pb - Cars	2 to 4 US cents/gallon, or 5% of ex refinery costs
Soil erosion control	Negative net present value of costs, on account of enhanced productivity of soils
Industry	[GATT and UNDO data to be summarized; figures average about 5% of value added in industry in OECD countries.]

- Stability reduces uncertainty and fosters confidence in the future. People can plan ahead, and weigh policies' longer term benefits. (More technically, stability lowers the social discount rate);
- Rates of saving and private rates of profit are higher; private agents can thus respond better to environmental taxes and regulations;
- Similarly, improvements in fiscal balances and savings leave the public sector better placed to finance environmental maintenance and investment activities;
- Price signals are clearer, and the application of the polluter pays principle is more likely to work.

There are also several respects in which well-designed environmental policies can facilitate stability. Energy taxation and congestion pricing (both crucial for achieving energy efficiency) are capable of raising significant revenues, while the removal of environmentally damaging subsidies for public services -- water and sanitation, transport, electricity generation, agrochemicals and forests -- would reduce economically undesirable losses in public revenue.

The next five sections of the paper discuss these linkages in a variety of more specific sectoral contexts. In each case, no contradiction is found between the aims of raising economic output and achieving environmental improvements.

II. POTABLE WATER AND SANITATION

Given their adverse consequences for economic growth and human welfare, chronically exception which proves a rule applicable to all water-borne diseases[9]: namely, that improvements in living conditions and hygiene are necessary adjuncts to the provision of water supply and sanitation facilities, if they are to have their most beneficial effects (see Box 2).

Between 1970 and 1988, water supplies were extended to approximately 1,200 million people in developing countries, and adequate sanitation facilities to nearly 700 million.[10] (The term "adequate" is usually taken to mean the proper disposal of human excreta using methods ranging from pit latrines to flush toilets.) These were very impressive achievements, which were encouraged by the Water Supply and Sanitation Decade initiated by the United Nations General Assembly in November 1980. Yet the task that remains is still very large. The population of developing countries increased by 1,000 million in the same period, while some 1,800 million people still lack access to adequate sanitation facilities and 1,300 million[11], to safe water (see Figure 1). In fact, both these figures seriously understate the magnitude of the problem, since problems of leakage, maintenance and low pressures are commonplace in many countries' water systems, while sanitation facilities defined to be adequate are often highly primitive.

There are two ways in which economic growth increases when water and sanitation facilities are made available to -- and hygienically used by -- those with little or no access. Recalling an earlier theme of the development literature, both are good examples of the economic returns to providing for a basic need:

- Cost savings are achieved by reducing the time and effort required to obtain water supplies and dispose of wastes.[12] Without public supplies people are forced to resort to using vendors and to fetching and carrying water from standpipes and wells or surface water. Surveys show (Box 3) this to be a considerable burden; a low income household consuming 20-30 liters/capita/day (lcd) (c.f. the OECD average of ≈ 300 lcd (?) for domestic uses, excluding gardens) typically fetches and carries 5 to 6 tonnes of water per month - often over considerable distances.

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[9] Thus: "[T]he worm infects individuals by boring through the skin, especially the skin of the foot. Infection produces lethargy and anemia through blood loss. The severity of the effect depends largely on the severity of the infection. Proper disposal of feces is a primary strategy in controlling this disease because if feces are not deposited on the ground, the worm will be unlikely to reach people's feet. ...[The] severity of hookworm is [thus] more affected by sanitation than is incidence and, following chemotherapy, sanitation may keep incidence low. An increase in wearing shoes and an improvement in general living conditions should also be effective." Ibid, pp 19-20.

[10] Excluding China.

[11] These last two figures also exclude China.

[12] When the night pail system is used, for example.

Box 2 Water supply, sanitation and hygiene education

A century and a half ago, a scourge from Bangladesh first showed the industrializing societies of Europe and North America how important water supply and sanitation could be for human health. The first world pandemic of Asiatic Cholera began in Bengal in 1817, and the disease reached Western Europe fourteen years later, in 1831. From there it spread with terrifying speed, and it reached North America the following year. The dramatic and fatal impact of the disease inspired and assisted the research of William Farr and John Snow, the founders of epidemiology. They showed how water supplies could serve to spread or to control the disease and gave urgency to the campaigns of Edwin Chadwick to provide water, adequate in quantity and quality, to the populations of the growing cities of the time.

Chadwick first argued the need to integrate water supply improvements with sanitation. He also emphasized the economic benefits that their health impact could bestow, remarking "that the expense of public drainage, of supplies of water laid on in houses, and of means of improved cleansing would be a pecuniary gain, by diminishing the existing charges attendant on sickness and premature mortality (Chadwick 1842). More graphically, the conditions of sanitation in industrial countries at that time are typified by the case of London, described in all their horrifying detail in the classic works of Dr. Hector Gavin, notably in his Sanitary Ramblings. Almost any page of this work contains descriptions such as the following:[a]

> Pleasant Row ... Immediately facing Pleasant Row is a ditch, filled with slimy mud and putrefying filth, which extends 100 feet. The space between Pleasant Row and the central square is beyond description, filthy; dung-heaps and putrefying garbage, refuse, and manure, fill up the horrid place, which is covered with slimy fetid mud. The east end has likewise its horrid filthy fetid gutter reeking with pestilential effluvia; the southern alley is likewise abominably filthy ... I entered one of these houses on the southern side, and found that every individual in a family of seven has been attacked with fever ... the privy of this house is close to it, and is full and overflowing, covering the yard with its putrescent filth ...

It is not surprising that deaths from typhus alone in mid-nineteenth century England were nearly 20,000 a year, and that 60,000 deaths a year were attributed to tuberculosis, not to mention high death-rates from numerous other diseases associated with insanitary and unhealthy living conditions. As Hans Zinsser remarked in his famous history of epidemics and of typhus fever, "as soon as a state ceases to become agricultural, sanitary knowledge becomes indispensable for its maintenance"[b]

Cholera and other diseases of poor sanitation are no longer a threat to Europe and North America, but Chadwick's words still have meaning for those who seek to promote water supplies and sanitation in the developing countries today. Indeed, the provision of adequate water supplies and excreta disposal has been acknowledged for more than a century as an essential public health measure with significant public health benefits.

Yet surprisingly it has been difficult to demonstrate the connection between improved water supply and sanitation facilities on the one hand and health on the other. One problem is colinearity - many other factors such as improved housing and earnings are associated with health improvements. Another crucially important factor, more difficult to measure, is hygiene, and yet another is whether the facilities are properly maintained. It is only recently that special purpose surveys have found the expected relationships.[c]

A recent background report for the IDWSSD concluded[d] that the benefits of improvements in water supply and environmental sanitation to health and social and economic development are a result of many different interacting factors. Health benefits are both direct and indirect. Thus well-designed projects combining water supply, excreta disposal and hygiene education can be expected to reduce mortality by an even greater extent, except in cases where other interventions, such as oral rehydration programs, have already substantially reduced diarrheal morbidity.

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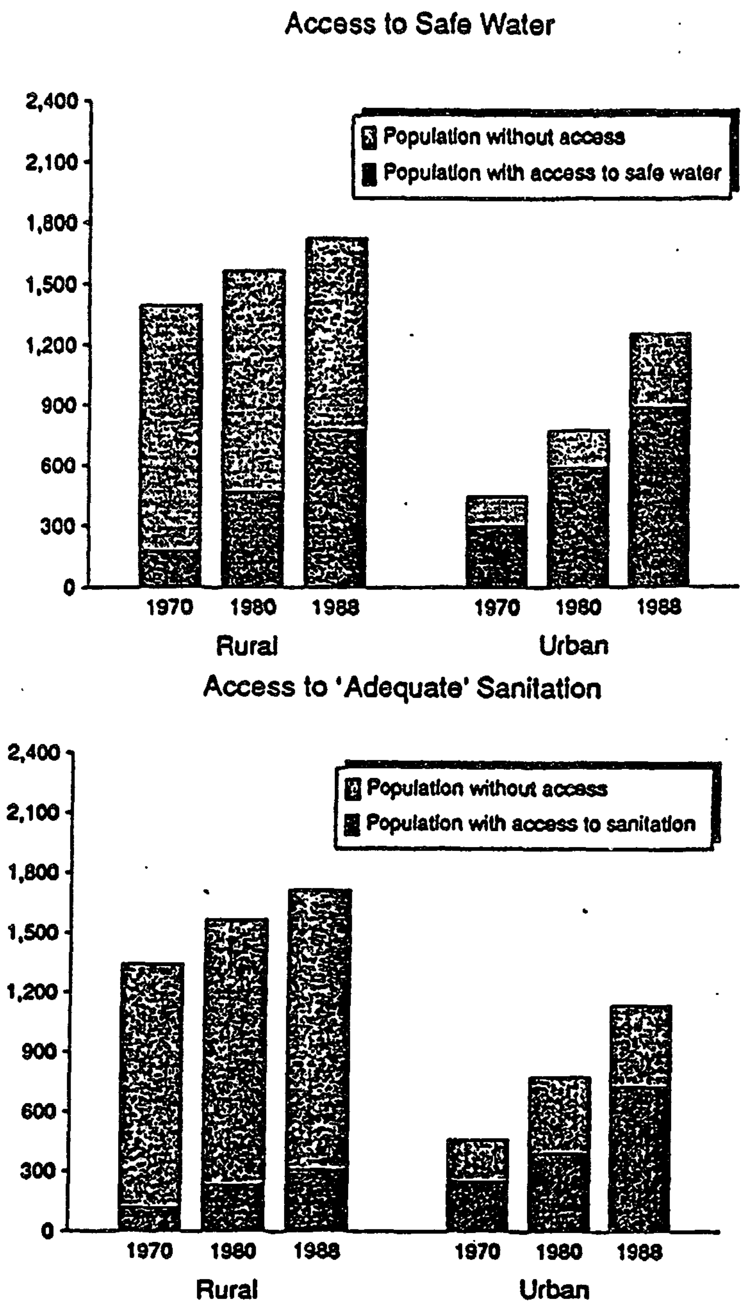
a. Quoted from Beckerman (1974)
b. Zinsser (1934) Rats, Lice and History
c. See the USAID review. op.cit (1990), the UNDP-World Bank Sanitation Study Report No. 1, Bangladesh (1990), and the Background Report by the Global Consultation on Safe Water for the 1990s, New Delhi, Sept 1990; World Bank/UNDP.
d. op.cit. International Drinking Water Supply and Sanitation Decade.

Figure 1 Access to Water and Sanitation in Developing Countries, 1970-1988



Preliminary Figures from WHO data

• Health benefits, aside from being a source of welfare improvement, are also a source of productivity growth. When people are ill or debilitated by water-borne diseases to the extent described above, their earnings and their contribution to economic output and growth are clearly reduced. Similarly, when children suffer multiple attacks of diarrhoea per year (as many as ten attacks per child per year have been reported in some regions -- see Table 3) their education, development, and in the long term, their contributions to their country's economic development suffer also.

The cost of investing in public supplies varies appreciably between regions and with pressures on available water resources. Costs are rising in many areas as a result of groundwater contamination, excessive drawdown of local aquifers, and urban expansion; all these factors require utilities to search for more remote, higher cost supplies. In developing countries, the average incremental cost of public water supply has doubled over the last twenty years to roughly $0.6 per cubic meter.[13] Yet in the present circumstances, the benefits of increased supply are substantial; conservative estimates, which neglect numerous intangible health benefits intangibles, show that water costs may be up to two or three times higher in cases where public supplies are not available (see Box 3). Every $3 to 4 invested in public water provision therefore returns a permanent $1 increase in real income. Comparable data are not readily available for combined sanitation and water supply, but the conclusion that their

Table 3 Summary of morbidity results from 276 surveys in children aged 0-4 years using the WHO/CDD methodology*, 1981-86

Region	Number of surveys (countries)	Annual incidence rate (episodes/child/year)** Median	Range
Latin America and the Caribbean	12 (8)	4.9	0.8-10.4
Sub-Saharan Africa	67 (22)	4.4	1.6-9.9
Middle East and North Africa	47 (10)	2.7	2.1-10.8
Asia and the Pacific	150 (20)	2.6	1.1-5.7
-India		2.7	
-China		1.2	
-Other		2.6	
All regions	276 (60)	3.5	0.8-10.8

Source: Jamison and Mosley (1990).
* Survey mostly conducted in geographically limited areas; if more than one survey conducted in any country, the country median was used to calculate the regional and global medians.
** Survey estimate adjusted for seasonality where appropriate data were available.

[13] World Bank Water Supply and Sanitation Sector: Review of FY90 Activities.

provision is a means of raising real incomes and output, as well as health and welfare, is nowhere disputed.

Furthermore, the gains per unit of investment would be greater if two inefficiencies were corrected: wastes resulting from subsidized production practices (table 4.4 below), and wastes from leakages in supply networks. Both cause excessive exploitation of an often scarce resource, raise supply costs and, in many cities (Bangkok, Lagos, and Mexico City are commonly cited examples) further deplete aquifers. Moreover, by undermining utilities' revenue base, they also undermine the financial capacity to expand supplies. "Water efficiency," like "energy efficiency," is a desirable means of raising supplies per unit of investment; another is the use of those low cost water and sanitation options that emerged during the Water Supply and Sanitation Decade, 1980-90.

Box 3 Water, Sanitation and Economic Output

Recent surveys have found that people without convenient access to safe water frequently pay more for the water they obtain--from vendors and through carrying it from the nearest standpipe, well or river --than they would for the full costs of providing it from public supplies. A survey in Onitsha Nigeria by Whittington, Lawria and Mu (1991) found that households alone were paying water vendors about $7m annually, an amount that would have been sufficient to provide for the two-thirds of the full capital, operating and maintenance costs of piped water to 80 percent of the population. This excludes the revenues that would be obtained from sales to industry and commerce, or the amounts that people would be willing-to-pay for water--such as that used for washing and sanitation--not usually provided by vendors. In a separate survey in Kenya, they found that the time spent hauling water was a significant cost imputed at between 50 and 160 percent of the unskilled wage rate. C.f. the following data from a survey in Lagos (figures in Naira/m^3):

Marginal Costs of Public Supplies		1.5
Alternatives to Public Supply:		
Tankers	40 gallons for N2	11.0
	200 gallons for N10	11.0
	1000 gallons for N20	4.2
Vendors	8 gallons for 40 Kobos	11.0
	40 gallons for N1.0	5.5
	1000 gallons for N20.0	4.4
Household Expenditures		
Low income households (30 lcd)		1.6 to 2.4
Average (50 lcd)		1.9 to 2.8
Household Expenditures Plus Labor Costs		
Low income households		2.2 to 3.0
Average		2.2 to 3.1

Source: A survey of 800 households in 1985, undertaken in preparation for a water supply project. 1985 prices. The labor costs were based on time spent hauling water times 50% of the going wage rate for unskilled labor.

But it is the health benefits of water and sanitation which many still believe are the more important--from an economic as well as a welfare perspective. However, these have proved more difficult to quantify. Data are required not only on morbidity, but on incomes lost through illness and debility for which special surveys are needed. Another complication is that the losses include not only those from recurrent illnesses such as diarrhoea, but those arising from periodic epidemics such as cholera and typhoid. It is unlikely that an appreciation of the importance of hygiene and the importance of safe water and sanitation are fully internalized in the above sorts of willingness-to-pay figures--if only to gauge from the numerous and graphic descriptions of open sewers, rotting garbage, public defecation and contaminated water that abound in water and sanitation studies. Willingness-to-pay figures, telling as they are, still greatly understate the economic benefits.

Box 3 Cont'd...

Reducing costs is another way of increasing the returns to and increasing the supply of water and sanitation facilities. Several technologies for lowering costs are available. Consider e.g. the following for sanitation:

Box Table 3.3 Financial Requirements for Investment and Recurrent Cost per Household (1978 U.S. dollars)

Facility	Total investment cost	Monthly recurrent cost	Facility	Total investment cost	Monthly recurrent cost
Low cost			Medium cost		
PF toilet	70.7	0.5	Sewered acquaprivy	570.4	2.9
Pit latrine	123.0	-	Aquaprivy	1,100.4	0.5
Communal facility a/	355.2	0.9	Japanese cartage	709.9	5.0
Vacuum truck cartage	107.3	1.6			
Low-cost septic tanks	204.4	0.9	High Cost		
Composting latrine	397.7	0.4	Septic tank	1,645.0	11.8
Bucket cartage b/	192.2	2.3	Sewerage (design population	1,478.6	10.8

Source: Kalbermatten, Julius and Gunnerson (1980)

Table 4 Average incremental costs (AIC) and prices (AP) of water

	AIC/m³	AP/m³	AP/AIC percent
Africa	0.65	0.29	45
Asia	0.47	0.17	36
EMENA	0.67	0.47	70
LAC	0.41	0.22	54
All projects surveyed	0.55	0.32	58

Source: FY90 Review of World Bank Water Supply and Sanitation Activities, based on a survey of projects.

In conclusion, there are thus two ways in which economic growth may contribute to the provision of water, sanitation, and the resultant benefits of both. First, growth helps to solve the financing problem of expanding supply; access to water supplies increases with per capita incomes (see Figures 2a and 2b), and over time with GNP growth (see the scenario in Figure 2c). Second, so long as development policies are broadly based and focus on poverty alleviation, growth contributes to the health benefits that result from an increase in the availability of sanitation and water supplies.

Figure 2(a) Access to water supplies in relation to per capita GNP

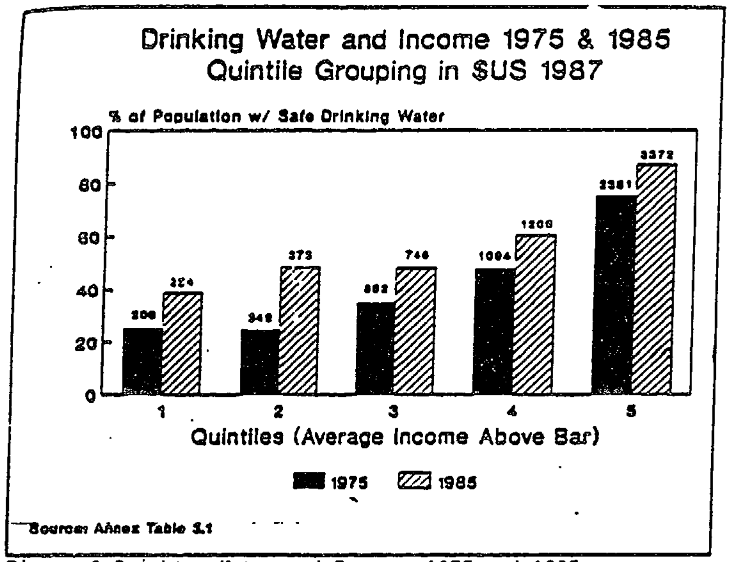


Figure 2 Drinking Water and Income, 1975 and 1985

Source: Beckerman, WDR Background Paper

Figure 2(b) Access to sanitation in relation to per capita GNP

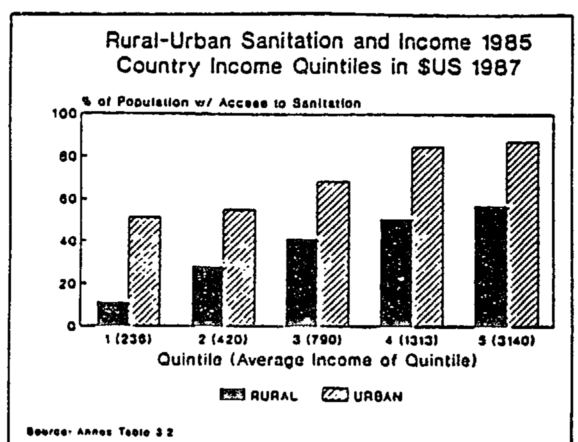
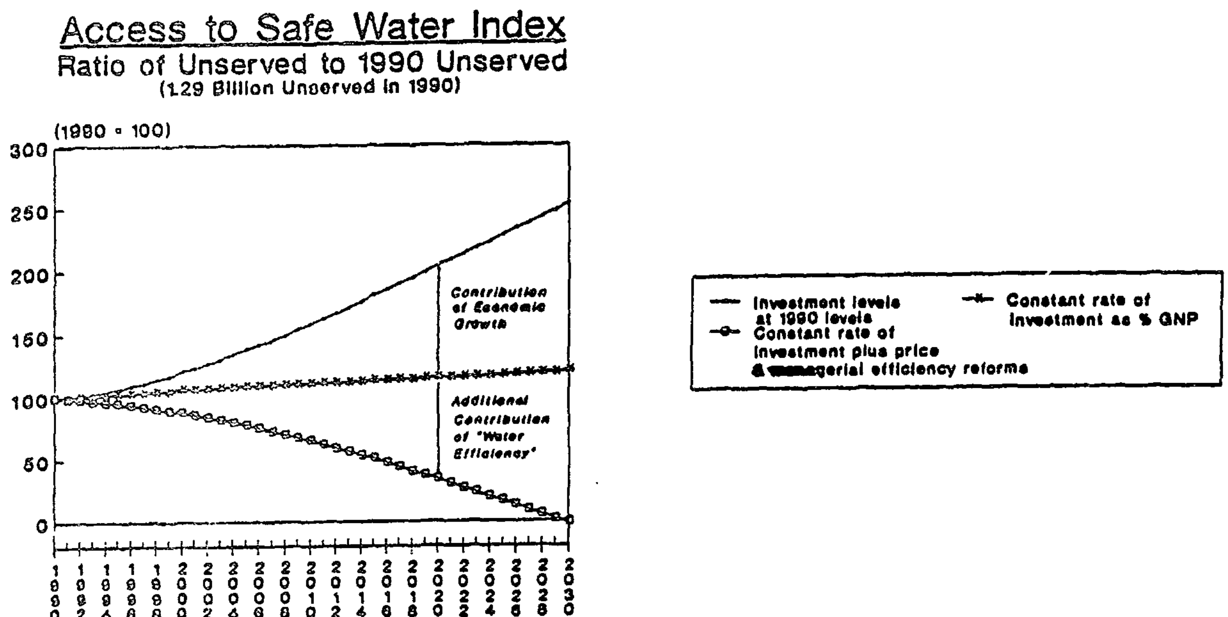


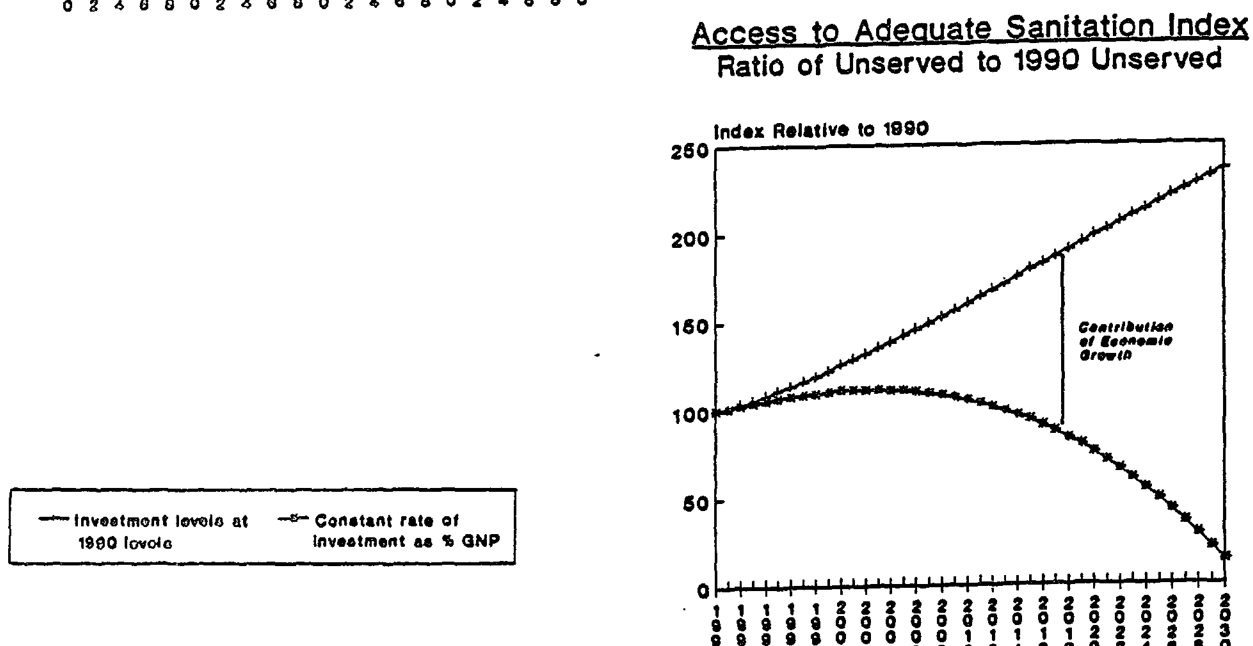
Figure 3 Rural-Urban Sanitation and Income 1985

Explanatory Notes:

The combined GNP of developing countries is approximately $3,500 billion, and gross investment $900 billion. Investments in water and sanitation are currently 1.6 percent of gross investment or $14 billion per year. In the 1980s investment led to an additional 600 million people being supplied with water and 400 million with sanitation. A growth rate of 4.5 percent per year would raise investment by 50 percent in the present decade and double it in fifteen years. This would help accelerate access to service. Making increased access more difficult however are rising service costs due to (i) the pollution and depletion of local aquifers in many regions, (ii) the need to turn to more remote and higher cost supplies as urban areas expand, and (iii) wastes arising from leakages in water supply networks (as high as 50 percent in some countries) and from widespread recourse to subsidizing service, which encourages waste by consumers and undermines the revenue base of the utilities.

Figure 2(c) Water and sanitation--long-term scenarios





Explanatory notes:

The scenario on access to safe water shows the number of people without service under three assumptions: (a) investment levels being at the 1990 levels of $10 billion p.a. (and thus assuming no growth of GNP); (b) investment rates being a constant proportion (1.7 percent) of total investment, the difference from (a) thus representing the contribution of economic growth to financing more access to service; and (c) the effects of reducing wastes and price inefficiencies in water supplies--which improves water availability and reduces costs. The calculations allow for rural-urban migration and for rising marginal costs of water in urban areas. The sanitation scenario is similar, except that there is no analysis of changes in managerial and price efficiency.

III. ENERGY: LOCAL AND REGIONAL POLLUTION

The combustion of fossil fuels -- for electricity production, transportation and industrial purposes, and household cooking and heating -- is the main cause of increasing urban and regional air pollution in developing countries, as it was historically in industrial countries during their urban-industrial expansion. The principal pollutants are sulphur dioxide, nitrous oxides, carbon monoxide, particulate matter and smoke, lead compounds, volatile organic compounds and ozone. Table 5 classifies these pollutants by principal source; Table 6 summarizes their main environmental effects.

Table 5 Principal Sources of Environmental Problem by Activity (Denoted by*)[a]

	Producer side[b]				End-Users:		
Problem Area	M;E&P	T&S	R&M	Electricity Generation	Industry	Transport	Domestic
Gaseous Emissions:							
SO_2, NO_X, CO, O_3, CO_2, Particulates, Lead Compounds, VOC and CH_4				*	*	*	*
Wastes							
Systemic:							
Effluents & Leakages	*	*	*	*			
Spent Materials & Plant	*	*	*	*			
Accidents & Spills	*	*	*	*			

Notes

[a] In actuality, practically all types of pollution can be identified with all sources, though of course some sources are much more significant for some types of problems than others. Thus reducing the levels of gaseous emissions from refineries is an important aspect of refinery design, and in reaching agreements on operating procedures and the choice of standards. The various options are well understood from a technical viewpoint, and design manuals and guidelines are widely available. But by far the greater source of gaseous emissions is that arising from combustion in end-use activities, in industry, transport and homes, and it is here where abatement policies related to such emissions need to be focussed. On the other hand, the problems of effluents, wastes, leakages, spills and accidents arise mainly on the industry side, much less in end-use. This suggests a classification of environmental problems according to principal source, as shown in the table.

[b] M = Mining; E&P, exploration and production; T&S, transport and shipping; R&M, refining and marketing.

Table 6 Environmental effects of major air pollutants

The environmental effects of air pollution can be classified into three groups. (i) Health effects - e.g. the bronchial problems associated with concentrations of sulphur dioxide in urban areas, particulates, smogs and photo-oxidant formation. The use of leaded fuels, still prevalent in developing countries, is another concern. The table summarizes the WHO guidelines on air pollution and the effects of various pollutants. (ii) Forest, soils and water. In parts of Eastern and Western Europe there has been extensive damage to forests, much of it attributed to acid deposition. (Few accurate assessments are available on the scale and nature of the problem in developing countries.) Soil acidification occurs if the soil's ability to neutralize acidic inputs becomes exhausted. In addition to the potential damage to trees and crops, the effects often extend to the acidification of streams and lakes, which become unable to support life. Roughly one third to one half of the deposition may occur outside the country responsible for the emissions of SO_2 and NO_X.[a] (iii) Buildings and Materials. Again the main problems are acid attack and particulates, leading to erosion, corrosion and discoloration.

Pollutant Effects	WHO Guidelines	
	Annual mean (ug/m³)	98* percentile (ug/m³)
Sulphur dioxide: Exacerbations of respiratory illness from short-term exposures; Increased prevalence of respiratory symptoms, including chronic bronchitis from long-term exposures	40-60	100-150
Suspended particulate matter: As for SO_2: Combined exposure to SO_2 and SPM are associated with pulmonary effects	Black smoke:	
	40-60	100-150
	Total Suspended Particulates:	
	60-90	150-230
Lead: Blood enzyme changes Anaemia; Hyperactivity and Neurobehavioural effects	0.5-1	
Nitrogen dioxide: Effects on lung function in asthmatics from short-term exposures	1 hour	24 hours
	400	150
Carbon monoxide: Reduced oxygen-carrying capacity of blood	15 min (mg/m³)	30 min (mg/m³)
	100	60
	1 hour (mg/m³)	8 hours (mg/m³)
	30	10
	COHB:	2.5-3%

* The 98 percentile (or P98) value stipulates that 98% of the daily averages must fall below a given concentration. This means that less than 2%, or less than 7 days per year, may exceed that concentration.

Source: UNEP/WHO (1988) Assessment of Urban Air Quality (Based on GEMS data).

a See statistical annex, Table 2.

Because of the limited number and quality of pollution monitoring facilities, neither the extent and growth of air pollution, nor its impact on the developing country populations, is known accurately. However, some cities are in danger of repeating the experience of industrial countries during their urban-industrial expansion; namely, the often severe intensification of environmental problems caused by the combustion of fossil fuels, before their successful resolution. The case of Cubutao in Brazil, for instance, evokes memories of the "killer smogs" of London less than forty years ago (see Box 4) - not least because in both cases it took crises of major crises to force governmental introduction of the required abatement policies.[14] Air pollution in many cities of developing countries now in the throes of industrialization, is far worse than in the industrial countries of the OECD:[15]

- In numerous cities, suspended particulate matter loadings exceed 230 ug/m^3 between 200 to 300 days per year. These are well above WHO guidelines, which propose a mean daily standard of 40 - 60 ug/m^3 and a less than 2 percent chance of a daily mean exceeding 100-150 ug/m^3.
- Sulphur dioxide concentrations are also high in those countries relying on high sulphur fuels. (Desulphurization processes are not widely practised in developing regions.) Figure 3 provides more information for selected cities. According to a UNEP/WHO report, over 600 million people live in urban areas where sulphur dioxide pollution exceeds WHO guidelines; for suspended particulates, the figure is 1,000 million.[16] Since rates of urbanization and energy consumption per capita are rising rapidly in developing regions, pollution problems will intensify appreciably in the coming years, even if aggressive abatement policies are put in place.

In terms of the inter-relationship of economic growth and the environment, energy production and use raises three issues: the growth of demand for fossil fuels, the technological possibilities for pollution abatement and their costs, and the impact on growth of using these technologies.

1. Energy demand: growth and geography

All available analyses show developing countries emerging as the major growth centers for commercial energy demand(Figure 4.4). In 1970, their combined primary energy demands amounted to 16 mbdoe or 15% of a world total of 104mbdoe. By 1990 this had almost tripled to 45 mbdoe or to 27 percent of a world total of 165 mbdoe; and this despite the oil price shocks and financial instabilities of the period. While the markets of the industrial countries (including Eastern Europe and the USSR) have matured and, with energy efficiency improvements, could conceivably peak or decline in the coming decades, developing country markets continue to grow at high rates of around 5 to 6 percent per year, and, given economic recovery in Latin America

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[14] Although these are extreme cases -- both particulate matter and SO_2 loadings reached several thousand micro-grams per cubic meter (ug/m^3) in the infamous London fog of 1952 -- daily average levels of 1,000 to 2,000 ug/m^3 have been recorded in Ankara, more than ten times the WHO guidelines.

[15] See Statistical Annex table 1 for further data.

[16] Global Pollution and Health, UNEP (1987).

Box 4 The London Smog of 1952 - and Cubatao in the 1980s

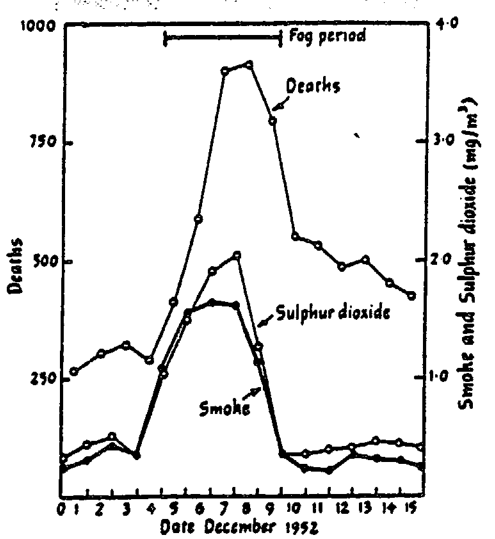
While air pollution can be abated in the course of urban-industrial expansion, it too frequently takes a crisis to bring the required policies into effect. Contrast the smogs (now a thing of the past) in London with the recent experience of Cubatao, Brazil.

The "killer smog" of 1952 was a turning point for smoke abatement policy in Britain. In the week following an "unusually nasty fog .... the Minister of Health was asked .... how many additional deaths had occurred in the metropolitan area. [He] replied there had been 4703 deaths compared with 1852 deaths in the corresponding week in 1951. At the end of January 1953, some six weeks after the fog, the London County Council issued a dramatic report on the fog. It gave figures for the excess of deaths per million inhabitants over the normal number in the LCC area attributable to four disasters between 1866 and 1952. The figures are shown in the table:

Date:week ending	4.8.1866	20.12.1873	19.11.1918	13.12.1952
Cause	cholera	fog	influenza	fog
Total deaths	876	713	1085	745
Normal number of deaths	450	470	300	300
Excess deaths over normal	426	243	785	445

"The ultimate number of deaths attributed to the 1952 smog was, of course, much greater (a total of some 4000), for many people who survived the week ending 13 December died later on from circulatory or respiratory disorders brought on by the smog. The grim lesson from these figures was that fog in the mid-twentieth century was as dangerous a killer as cholera had been in the mid-nineteenth century.

"This information was not new: Rollo Russell published data just as grim as far back as 1880. But this time, in 1952, the incident crystallized public opinion in the perplexing way such incidents do. It is true that there were better and cheaper means for abating smoke in 1952, than there were in 1880, but it would be a gross over-simplification to attribute the impact of the 1952 smog, compared with the lack of impact of scores of earlier fogs, to a change in technical and economic circumstances alone. The overriding circumstance was the ripening of public opinion."[6] The actual levels of pollution recorded are shown in the figure (taken from Brimblecombe 1987) who comments that the highest daily mean recorded was 4460 ug/m^3, but over shorter periods it would have been much higher, possibly as high as 14,000 ug/m^3 - "a phenomenally high level".



Deaths and pollutant concentrations during the London smog of 1952

... Box 4: continued

c.f. Findley's summary of the crisis that led to a pollution abatement program in Cubatao, Brazil:

"Additional air quality monitoring by scientists at the University of Sao Paulo had disclosed, in the dust and smoke perpetually shrouding the city, 'an infinity of ... chemicals, invariably toxic,' as well as sulfates, phosphates, and nitric and phosphoric acids, in concentrations 'at least a dozen times higher than the maximum acceptable levels."

"On September 3, 1984, in the midst of an atmospheric inversion, officials of CETESB and SEMA visited Cubatao. A few hours later the governor of Sao Paulo, for the first time ever, decreed a "state of emergency" in Cubatao, citing particulate concentrations in excess of the ambient standard of 875 micrograms per cubic meter. CETESB promptly required nine industries in Vila Parisi to shut down and ordered residents to evacuate the district. Police were sent from the city of Sao Paulo to assist in the evacuation and to prevent looting of empty homes. Although the mayor of Cubatao protested that he had not been consulted before these measures were taken, he agreed to make the soccer stadium available for displaced residents and to provide food and blankets. Eventually, atmospheric conditions improved, the state of emergency was downgraded to a state of alert (defined as concentrations of particulates in excess of 625 micrograms per cubic meter), the eighth such alert of 1984, and people were allowed to return to their homes. A few months later, in the early morning of Saturday January 26, 1985, there was a massive, prolonged release of ammonia gas from a ruptured pipe at a fertilizer plant in Vila Parisi. Six thousand residents were evacuated; more than sixty persons were hospitalized. On Sunday, after the gas had dissipated, people were allowed to return to their homes. On Monday, CETESB assessed a penalty of twenty-four million cruzeiros against the owner of the plant. Later that day, after the Governor of Sao Paulo said the penalty was too small, the mayor of Cubatao signed a decree ..."

"Since 1985 there has been real progress toward ameliorating some of the worst aspects of the environment fiasco in Cubatao. A tremendous amount of pollution control equipment is being installed in industrial plants, which also have been switched to less-polluting fuel, thousands of residents are being assisted in relocating to more suitable living areas, CETESB has become more aggressive in using fines and temporary plant closures to deal with recalcitrant polluters, and the Ministerio Publico has initiated public civil actions seeking restoration of damaged wetlands, waterways, and hillsides. Moreover, through extensive national newspaper and television coverage of the agony and progress of Cubatao, all of Brazil has received an environmental education."[b]

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[a] Ashby and Anderson (1981)
[b] Findley (1988).

and Africa, may even rise above this range. Even under an "energy efficient" scenario (where growth rates are between one and two percentage points below the trend growth rates in these regions), developing countries' primary energy demand would probably exceed 100 mbdoe in the next twenty years or so, and perhaps 200 mbdoe by the year 2025. Yet their per capita consumption levels would still be low relative to those of the industrial countries today (see notes to Figure 4). There are several reasons why demand growth is likely to be so rapid in developing countries:

- Low per capita consumption levels. These are less than one tenth of industrial

Figure 3 Average air pollution levels in selected cities, 1980-84

(a) Suspended particulate matter (micrograms per cubic meter)

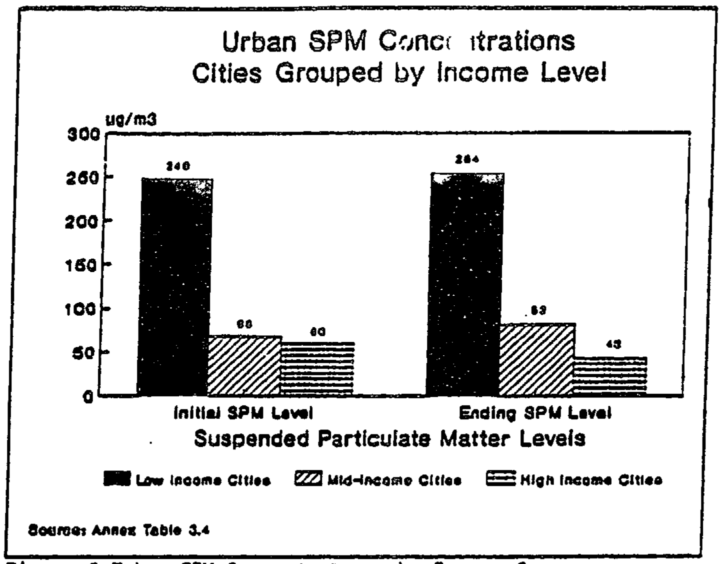


Figure 3 Urban SPM Concentrations by Income Group

Source: Beckerman, 1992.

(b) Annual SO_2 average concentrations (micrograms per cubic meter)

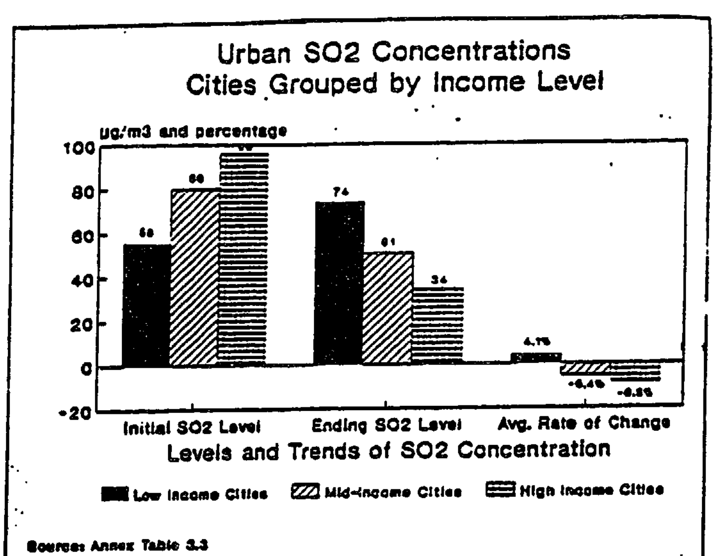


Figure 4 Urban SO_2 Concentrations by Income Group

Source: United Nations Environment Program and World Health Organization (198) Assessment of Air Quality (based on GEMS' data). Beckerman, 1992.

country levels; income elasticities of demand, which have declined in the industrial countries, are still high;[17]

• Population growth: still about 2 percent per year, and though United Nations and World Bank projections show a declining trend, developing country populations are likely to rise from around 4 billion today to 7.5 billion over the next forty years;

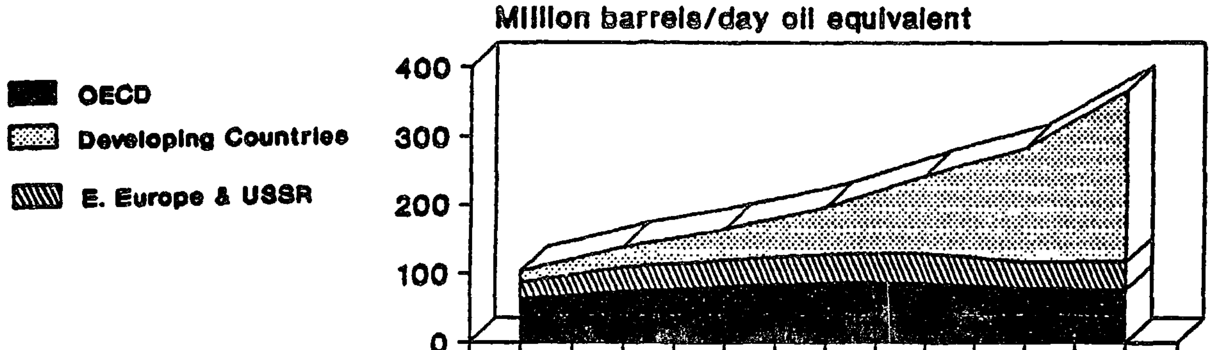
• Per capita income growth. Long term per capita income growth rates are about 4 percent in Asia; assuming economic recovery, they are prospectively the same in Latin America and over 2 percent in Africa;

• Urban-industrial expansion. On average, urban populations are still about 40% of the total, and are expanding at 5 to 6 percent per year. Industrial expansion is also rapid in East Asia (around ten percent per year) and South Asia (7.5 percent), but has stalled in Latin America;[18]

• Substitution of fossil fuels for firewood. The latter accounts for perhaps one half of energy supplies in developing countries[19] and is itself a significant source of environmental damage.

Without the introduction of pollution abatement technologies, therefore, urban pollution levels in developing countries will probably increase by a factor of four or more over the next two decades. However, abatement technologies have been developed for all categories of

Figure 4 An "energy efficient" demand scenario, 1990-2030



	1970	1980	1990	2000	2010	2020	2030
Developing Countries	16	29	45	68	113	166	249
E. Europe & USSR	23	35	38	41	43	38	40
OECD	65	75	82	88	87	79	78

[17] See Dunkerley (1991) for a compilation of evidence; see also Barnes and Imran (1990).

[18] See World Development Report 1990, World Bank, Statistical Annexes.

[19] See Leach et.al. (1986), Dunkerley (1991) and Pearson (1988) for case studies and informative discussions.

Basis of Figure 4:

	Actual			Scenario			
	1970	1980	1990	2000	2010	2020	2030
Barrels of oil equivalent/capita/year							
OECD	36	39	40	41	39	35	34
E. Europe + USSR	24	34	35	35	40	35	35
Developing countries	2	3	4	5	7	9	12
Populations							
OECD	660	700	756	790	810	825	830
E.Europe + USSR	345	375	402	425	450	470	485
Developing countries	2650	3310	4085	5000	5900	6750	7575

Table 6 Electric power generation statistics, 1980-89

	Total generation, GW		Growth rate,	Thermal station output 1989	
	1980	1989	% per year	GWh	% total GWh
OECD	4,730	6,400	3.7	3,770	59
E.Europe & USSR	1,560	2,080	3.2	1,580	76
LDCs	1,060	2,050	2.9	1,425	61
-of which China	(280)	(510)	(6.9)	(400)	(78)
India	(110)	(230)	(8.9)	(180)	(78)
Total	7,350	10,530	4.1	6,775	64

Source: United Nations Energy Statistics/and International Energy Annual (1991).

pollution: electricity generation, motor vehicles, and industrial and household use. In addition, what has come to be called "energy efficiency" could contribute significantly to pollution abatement.

2. Abatement technologies and practices: electricity generation

Fossil-fired power stations account for two-thirds of the world's electricity generating capacity of 2.6 million megawatts, for 30 percent of fossil fuel consumption, and for more than half the consumption of coal. In the 1980s, electricity generation rose by 60 percent in the industrial countries and by over 110 percent in the developing countries, where demand is expanding at 8 percent per year (see Table 6), requiring roughly 50,000 MW of capacity additions each year. Coal-fired stations are the main source of emissions both because they make up more than half of total thermal generating capacity and because of the high sulphur content of coal in many regions. Combustion inefficiencies are often considerable and modern emission control technologies are not widely deployed (see Box 5); this gives rise to high emission rates for particulates, smoke and carbon monoxide.

There are four broad options for reducing harmful emissions: (1) substitution of low sulphur coals, oil and gas; (2) emission control technologies, principally mechanical and electrical methods (electrostatic precipitators or ESPs) of removing particulates from flue gases, flue gas desulphurization (FGD or "scrubbers") and catalytic devices for reducing NO_X;

Table 7 Typical Emission Characteristics and Thermal Efficiencies New Fossil-Fired Power Plant

	Emission Control Technology	Emissions Tonnes per MW-year			Percent Abatement Relative to Coal(3%S)			Thermal Efficiency percent
Fuel and plant type	Technology	PM	SO_2	NO_x	PM	SO_2	NO_x	
Coal(3 percent Sulphur)[a]								
-conventional boiler	none	234	180	41	0	0	0	34.0
-conventional boiler	ESP	1	180	41	>99	0	0	34.0
-conventional boiler	ESP/FGD	1	18	41	>99	90	0	31.1
-conventional boiler	ESP/FGD/ LowNO$_x$/SCR	1	18	4	>99	90	90	33.1
-FBC	ESP	1	27	23	>99	85	56	33.8
-PFBC/CC	ESP	1	13	20	>99	93	50	38.9
-IGCC	None	1	2	21	>99	99	50	38.0
Residual fuel oil (3 percent S)								
-conventional boiler	None	8	126	36	97	30	12	35.2
-conventional boiler	ESP/FGD	0.04	13	36	>99.9	93	12	35.2
-conventional boiler	ESP/FGD/ LowNO$_x$/SCR	0.04	13	36	>99.9	93	90	34.4
Natural gas								
-conventional boiler	None	0.3	0.7	26	99.9	99.9	37	35.2
-conventional boiler	LowNO$_x$/SCR	0.3	0.07	9	99.9	99.9	78	35.2
-combined cycle	None	0.2	0.06	4	99.9	99.9	90	44.7

a. Coal cleaning is sometimes used to remove some of the sulphur prior to combustion, mainly the iron pyrites (FeS^2), though for organic sulphur that is chemically part of the coal molecule, emission control or the new combustion technologies are preferred. Chadwick et.al (1987).

Notes:

FBC	=	Fluidized bed combustion
PFBC	=	Pressurized fluidized bed combustion
CC	=	Combined cycle
IGCC	=	Integrated coal gasification combined cycle
ESP	=	Electrostatic precipitators
FGD	=	Flue gas desulphuration
Low NO_X/SCR	=	low NO_x emissions using selective catalytic reduction devices.

Source: Based on OECD(1989d) Energy and the Environment: Policy Overview. The OECD report treats each abatement technology separately. The estimates for combinations of technologies to treat two or all three pollutants together are inferred form their data.

Box 5 Coal fired power stations in India and China

The world's largest producer and consumer of coal is China; it has reserves of 600 billion tones, and produces and consumes over 1 billion tones per year (US production is roughly 0.7 billion tones per year); 40 percent of the reserves have a sulphur content of over 2 percent and 20 percent of over 3 percent. Between 1980 and 1985 total SO_2 emissions rose by 45%, from 5.6 to 8.2 million tones. The release of particulates is reportedly an even bigger problem. Since 1980, electrostatic precipitators have been standard in new plants greater than 100 MW (they have been standard in Europe and the US since the 1950s) but many plants are much smaller than this, and "in terms of thermal efficiency, capital costs, operating costs, dispatching capabilities, and the environmental impacts, the small plants are inferior to larger plants [see box table 3.5]... These smaller plants release into the atmosphere three to eight times more particulates per kWh than do the larger 200 MW plants."

Box Table 3.5 The unit costs of large versus small power plants in China

	200 MW plant	12 MW plant	Percent difference
Capital costs in 1986	¥1250/kW*	¥1540/kW to ¥1680/kW	+23-34%
Average coal consumption	412 g/kWh	660 g/kWh	+60%
Thermal efficiency†	31%	19%	-40%
Total operating costs‡	¥0.0475/kWh	¥0.064 to ¥0.076/kWh	+35-60%
Pollution controls	Electrostatic Precipitator	Venturi cyclone	
Dust collection Efficiency	90-95%	65-75	

Source: Wirtshafter and Shih (1990).

(3) advanced, high-efficiency, low-emission technologies such as fluidised bed combustion cycle technologies; (4) efficiency in the production and use of electricity -- or what has come to be called "energy efficiency." Table 7 summarizes a recent OECD assessment of the abatement efficiencies of alternative fuels and various combustion and emission control technologies.

Clearly apparent in the data are the environmental advantages of switching to natural gas -- over 99.9 percent reductions in particulates and SO_2 relative to conventional coal-fired boilers with poor or no emission control technologies. The use of combined cycle technologies in gas-fired stations also promises to reduce significantly NO_x emissions per unit of energy produced, on account of increases in the thermal efficiencies of the power stations and better control of combustion temperatures. Current efficiencies of combined cycles are over 45 percent and prospectively 50 percent and above[20], almost twice those of conventional coal fired stations thirty five years ago.

However, the technological response of the coal and electricity generation industries to environmental problems has been remarkable; five developments, in particular, should be noted. First, coal cleaning technologies have been developed; these are designed to reduce the nonburning mineral matter (ash) and the sulphur content of coal. The cleaned coal has a higher heat value and there is a lower ash load on the boiler.

Second, the mechanical and electrical devices for removing particulates that have been introduced in the industrial countries over the past forty years, can now successfully remove over 99 percent of particulates. Improvements in combustion technologies and thermal efficiencies have eliminated carbon monoxide emissions to such an extent that in the industrial market economies they are regularly no longer classified as a significant pollutant from power stations. (However, as can be seen from the data on China and India, the benefits of such gains have yet to be satisfactorily incorporated into coal fired power stations in many developing countries -- see Box 5).

Third, there is the development of flue gas desulphurization technologies, which are capable of removing over 90 percent of sulphurous emissions, albeit at some cost. (Scrubbers are also being developed for the control of NO_X.) The following comment on the relevant US experience is worth quoting because it provides not only information on costs, but also insights into the teething problems of incorporating a new technology into power systems on such a large scale:[21]

> "wet scrubbing is a simple concept but is difficult and expensive to carry out in practice. An alkaline substance, usually lime or limestone, is mixed with water to form a slurry that is sprayed onto the flue gas. The sulphur oxides in the flue gas are absorbed by the slurry and precipitate out of the liquid as inert calcium sulphite or sulphate (gypsum)..... Scrubbers have been required on all pulverized-coal power plants in the US whose construction began after 1978..... In a new plant the scrubber typically costs between $150 and $200 for each KW of generating capacity..... a scrubber for an existing plant costs between 10 and 40 percent more..... Regardless of the age of the plant, the cost [of operation] is high. Scrubbers create huge amounts of sludge waste that must be put in holding ponds and landfills....

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[20] Combined cycles use both gas and steam turbines to drive the generators. The gas turbines are powered by the hot gases emerging directly from the combustion chamber. Steam is also raised in the combustion chamber and by utilizing the still-hot exhaust gases of the gas turbines. The improvements in efficiency arise from the thermodynamic advantages of higher inlet temperatures to the heat engine (turbine).

[21] Balzheiser and Yeager (1987).

The widespread implementation of the technology has not been easy or cheap. The reliability of early units was considerably less than that of the plant as a whole; hence they required components that were either redundant or had been engineered with large margins of tolerance .... the technology was prematurely brought up to commercial scale. Only now, after a quarter-century of experience, have scrubbers approached an acceptable level of reliability."

The point here is that even when an environmental problem is understood and policies to address it are agreed upon[22], there may be appreciable lags in developing and installing corrective technologies. This is a generic problem in the electricity industry. The capital stock takes about thirty years to turn over, while retrofitting (as the above authors note) may not necessarily be a short-cut or cost-effective approach. Aside from the extra capital costs, there is also a 5 to 10 percent reduction of thermal efficiency (table 7).

A fourth development has been fluidised bed combustion, in which crushed coal is fluidised with limestone by supporting the particles on a strong rising current of air. The contact between sulphur compounds and limestone enables sulphur to be removed from furnaces directly; flue gas desulphurization is not needed, and SO_2 abatement efficiencies are in the range 85 to 95 percent. Better control of furnace temperatures also enables NO_X to be reduced significantly, while the turbulence of the fluidised bed leads to more efficient combustion.

Yet a fifth development is the merging of combined cycle technologies with fludised bed combustion. This can be achieved by either gasifying the coal before burning it to drive gas turbines, or using the hot gases from a pressurized (PFBC) version of a fluidised bed combustion chamber.[23] In both cases appreciable improvements in thermal efficiency have been obtained along with further reductions of SO_2 and NO_x emissions.

In short, the response of the coal and electricity industries to environmental problems in the industrial countries has been to develop technologies which in terms of emissions make using coal for power generation nearly as environmentally attractive as using gas. These developments led initially to cost increases, but over the longer term these may very well be offset by further efficiency improvements obtained from fluidised bed and combined cycle/coal gasification technologies.

Given the extent of coal and gas reserves in developing countries (see Figure 5), such developments provide a significant opportunity for pollution to be reduced even as electricity production expands to meet the needs of households, industry and commerce. Costs vary with the quality and availability of coal and gas, but, even in cases of low quality feedstocks, rarely exceed more than 10 to 20 percent of the capital costs of power stations, and may be offset over the longer term by rising thermal efficiencies. However, even with fairly aggressive policies, it will be some time before such developments can be incorporated in the capital stock, in part

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[22] This is itself a time consuming and disputative process, which lasted the better part of a century in the case of the control of smoke and particulate matter emissions from coal fires and boilers in the industrial countries.

[23] See Harrison (1988) and Balzheiser and Yeager (1987)

because of the longevity of power stations, typically some thirty years. Yet the possibilities for "delinking" environmental problems from electricity production are well-proven.

3. Abatement Technologies and Practices: Road Transport

Transport fuels account for over 60 percent of world oil consumption, 80 percent in the US and Canada, 65 to 70 percent in Europe, 43 percent in the USSR and 50 to 60 percent in other regions (see Table 8). Gasoline and diesel each make up approximately 45 percent of the transport fuels market, and aviation the remaining 10 percent (these figures exclude fuel oils for ships). Demand for transport fuels is increasing in most regions, as can be inferred from Figure 6, which shows the relationship between the extent of freight and passenger transport and GNP for several countries.

Table 8 Consumption of Oil by Transport, 1988. Million Tonnes

	Total	In transport	Transport as percent total[a]
Canada and United States	700	564	80
Europe (East and West)	590	390	66
USSR	446	192	43
Japan and Oceania	166	95	57
	1902	1242	65
Asia (excl. Japan)	451	227	50
Latin America	234	122	52
Africa	83	45	54
	768	394	51
Total	2670	1636	61

[a] Includes aviation fuels, motor gasoline and diesel oil but not those portions of kerosene and residual fuel oil used for transport, which are more difficult to identify.

Source: UN Energy Statistics Yearbook (1988).

Principal pollutants from motor vehicles are carbon monoxide, nitrogen oxides, volatile organic compounds and other evaporative emissions such as benzene, lead (when used as an octane enhancer), sulphur dioxide and particulate matter. The health and welfare effects of these pollutants, which have been studied extensively over the past forty years[24], have led to increasingly stringent regulations in OECD countries; these latter have in turn caused appreciable changes in the design of engines and emission control devices, and in the types of fuel used. Many of these developments have still to be fully incorporated into vehicle fleets, but the upshot has been a significant decrease in OECD lead emissions and a containment of other pollutants also. An OECD study reports that "urban lead concentrations have decreased ... in North

[24]See Annex 2 for a tabular summary of the health effects.

America, on average, by 85 percent per cent, and in large European cities by about 50 percent... [though] VOC and NO_x emissions have generally increased compared with the early 1970s...[because] motor vehicle fleets and kilometers travelled have increased in many countries at a much faster rate than the implementation of emission controls."[25] For new vehicles in the United States, emission standards are set such that emissions of CO, VOCs, NO_x and Pb are respectively 4 percent, 5 percent, 24 percent and 0 percent of the levels of twenty-five years ago and of those levels experienced in developing countries:

Table 9 Emissions Standards for New Gasoline-Powered Motor Vehicles: United States, Mexico and Brazil (Units of g/Km for CO, VOC and NO_x; mg/liter for Pb)

	Year	CO	VOC	NO_x	Pb[a]
United States	- Uncontrolled	54	5.4	2.5	130
	- 1968	32	3.7	3.1	
	- 1983	2.1	0.25	0.6	
	- 1990				.0 (unleaded) 26 (leaded)
Brazil	1989	24.0	2.1	2.0	uncontrolled
Mexico	1990	24.8	2.9	3.2	controlled

a OECD (1988) Transport and the Environment

Source: Faiz et.al.(1990).

In broad terms, there are two ways to reduce vehicle emissions, one technological and the other managerial; successful policies will involve both approaches. Technological options include engine modifications to improve combustion efficiency, such as changes in air/fuel ratios, ignition tuning, and advanced combustion technologies (for example high-compression lean burn engines); exhaust gas recirculation; and exhaust after-treatment, principally oxidation catalysts (which oxidize almost all the residual hydrocarbons and carbon monoxide in the exhaust stream) and "three-way" catalysts (so-called because of their ability to lower HC, CO and NO_x levels simultaneously).[26] Another technological development is unleaded fuels, which now dominate OECD gasoline markets. Table 10 summarizes some of the technologies for gasoline-fuelled vehicles, their costs and significant impact on emissions; parallel options are also available for diesel engines.

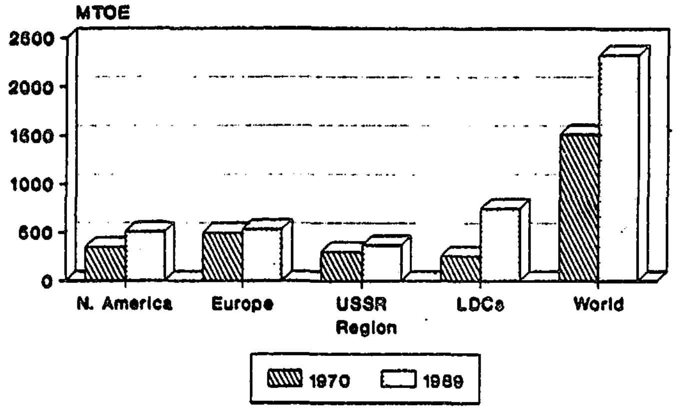
The predominant managerial option is a reduction of urban congestion. Congestion is a rising source of economic waste as well as of pollution -- in developing no less than in industrial countries - and policies to address it would provide a clear case of economic efficiency and pollution abatement policies working together (see Box 6). Despite the seeming

[25]Energy and the Environment OECD (1989) p49.

[26]See OECD (1988) Transport and the Environment.

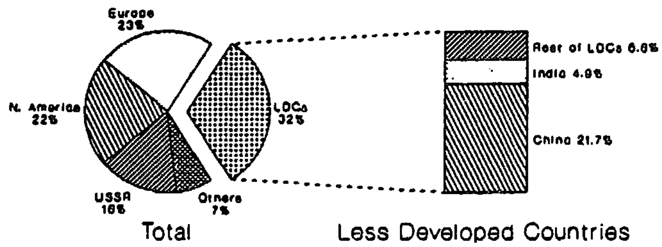
Figure 5 Coal consumption and reserves (in MToe)

Coal Consumption
1970 and 1989

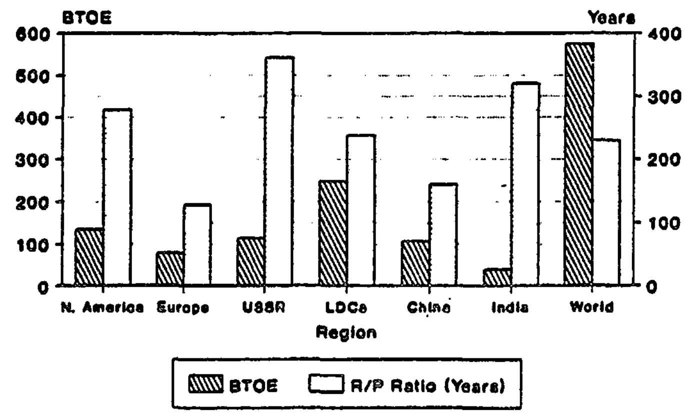


Source: World Bank data, BP Statistical Review of World Energy, June 1990.

Regional Breakdown of Coal Consumption
1989

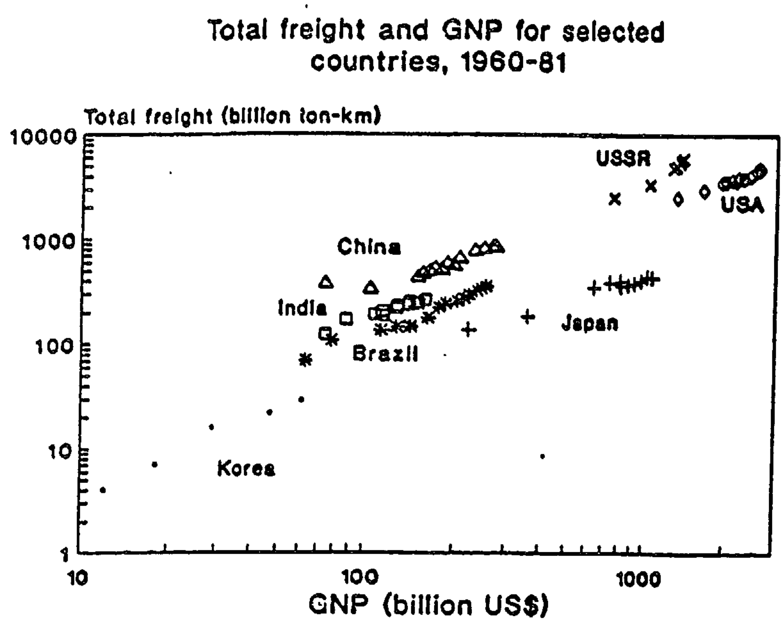


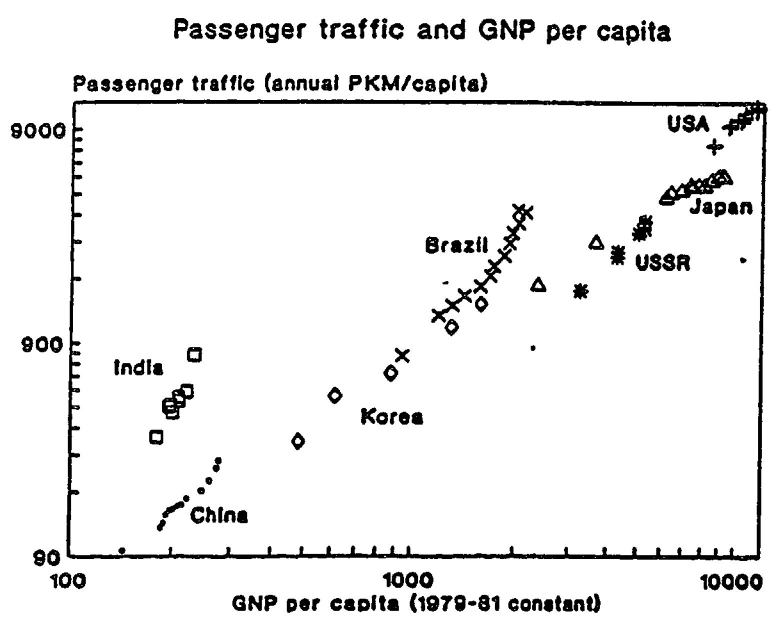
Coal Reserves
1989



Source. World Bank data. BP Statistical Review of World Energy. June 1990

Figure 6 Passenger and freight transport v GNP for selected countries, 1960-81.





Source: "Transport in China", Staff Working Paper No.723

Table 10 Exhaust emission control technology for gasoline-fuelled light-duty vehicles

Exhaust emissions for uncontrolled vehicles (four-stroke, spark-ignition): CO - 78 gm/mile; HC - 7.3 gm/mile; NO_x - 3.4 gm/mile

Control level	Type of Technology	Approximate cost per vehicle (1989)	Percent reduction in emissions[c] CO	HC	NO_x	Pb[c]
I.	Air pump, ignition timing, mechanical air-fuel ratio control.	\$60	40	50	-10	0
II.	Level I + EGR	\$100	50	60	20	0
III.	EGR + Oxidation catalyst + electronic ignition timing (lean burn)	\$400	80	85	50	100
IV.	EGR, 3-way catalyst	\$500-\$600[b]	95	95	80	100
V.	Level IV + Electrically-heated catalytic converter and other advanced technologies	>\$700	98	98	95	100

a Two-stroke engine vehicles could reach this level of control by use of timed fuel injections; increased fuel consumption and driveability problems experienced with level I and II systems could be reduced through more advanced engine technology. EGR = exhaust gas recirculation.

b Depending on the sophistication of the 3-way catalytic converter and level of precision in the control of air-fuel ratio.

c Control levels III and above require unleaded gasoline.

intractability of congestion, a combination of traffic management schemes and congestion pricing offer considerable promise.

Traffic management schemes are wide ranging and include: the segregation of motorized and non-motorized traffic through the provision of exclusive facilities for pedestrians and bicycles; controlling access to inner city areas; incentives for greater investment in, and use of, public transport; the designation of special lanes and routes, during peak hours, for buses and high-occupancy vehicles; the use of one way street pairs; improvements in signals and intersections; and the diversion of through traffic to environmentally less sensitive routes. It has been estimated that such approaches alone may reduce vehicle fuel consumption in metropolitan areas by over 30 percent[27], while accidents to pedestrians and cyclists - a major problem in developing countries -would also be reduced significantly.

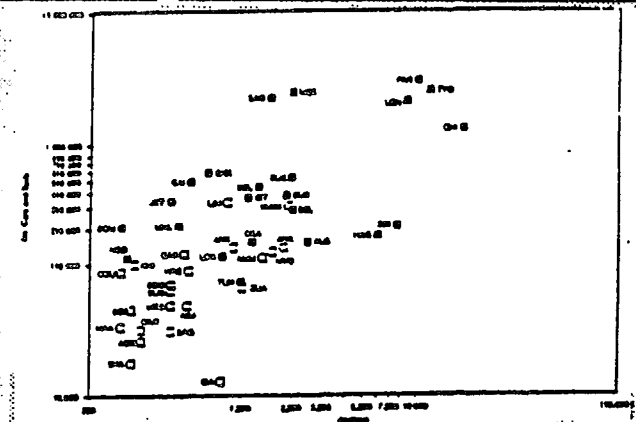
However, congestion pricing is potentially far the most important - and also the most neglected - instrument that governments can use to reduce congestion. Aside from its impact on pollution and congestion itself, it can potentially raise revenues sufficient to finance traffic management schemes of the sort listed above. Yet, despite the very successful example of the Singapore Area Licensing Scheme, it is a policy which public authorities - in industrial as well as in developing countries - are only now beginning to consider (see Box 6). In terms of its

[27] Faiz and Carbajo (1991), p24.

Box 6 Urban road congestion and its costs*

Congestion is intensifying in developing countries. It is in many industrial countries, and is a source of economic loss as well as being costly to the environment and human welfare. It increases travel times, road accidents, vehicle operating costs and emissions. There are broadly two measures available to deal with it. The first is through traffic management measures, including the management of street and off-street parking, and supplementing these with minor improvements. Such measures are generally sufficient for smaller cities with lower traffic densities, but are not for larger cities such as Bangkok, Manila, Cairo, Mexico City, Lagos and many others which (like many in the industrial countries) will remain seriously congested unless congestion charges are introduced (see Box 3.6 Figure).

Box Figure 3.6 Relationship between GNP per head and number of registered cars and taxis, 1985



▢ Cases where traffic management and road improvements would eliminate most congestion.

■ Cases where traffic management and road improvements would not eliminate serious congestion.

Congestion pricing policies along with a use of the revenues from such policies and road user charges for traffic management schemes would have the following benefits:

(a) Reduction in times lost in congestion [evidence to be obtained from INUTD], and a better mix of transport - public, private, passenger vehicles, and pedestrian and bicycle traffic. The development of the small commuter car would also be encouraged.

(b) Reductions in emissions and other environmental damage (such as noise and vibration). The cities worst affected by pollution from vehicles include Mexico City, Sao Paulo and Santiago in Latin America; Ibadan and Lagos in Nigeria; nearly all the megacities in Asia; Ankara, Cairo, Istanbul and Tehran in the Middle East; and most of the major cities of Eastern Europe. Without congestion pricing and pollution abatement policies problems of pollution will get worse.

(c) Reductions in accident rates. These are ten to twenty times higher per vehicle in developing than in industrial countries. The proportion of pedestrian casualties is high and a lot of accidents--particularly in Asia--involve pedal cycles and two-wheeled vehicles. The costs in terms of human suffering and, even, of economic output are enormous. Recent estimates of the annual costs of road accidents vary from 0.4 percent of GNP in China to 2 percent of GNP in African countries, based on estimates of medical costs and losses in output.

All these benefits would add to economic growth. In addition, the revenues would be appreciable. The following are some examples (figures in 1990 dollars)

	(1) Annualized costs	(2) Revenues	Ratio (2)/(1)
Singapore Area Licensing	2.4	13.2	5.3
Bergen	1.8	11.1	6.2
Stockholm	18.5	92.3	5.0
Oslo	16.3	95.8	5.9
Traondheim	2.3	22.4	9.7

*. Taken from a paper by Ian Heggie.

impact on economic growth there are numerous benefits: (i) gains in productivity and welfare through reductions in travel times; (ii) fuel savings; (iii) reductions in pollution from vehicle emissions; (iv) improvements in the capacity utilization of vehicle fleets; (v) a better and economically more efficient balance between public and private transport, including privately owned passenger vehicle services; (vi) a reduction of traffic accidents, now a leading cause of death and injury in developing countries, where road deaths per vehicle-Km are already ten times industrial country levels.

4. Conclusion: Energy Consumption, Pollution Abatement and Economic Growth

The proceeding discussion leads to four conclusions:

• The "delinking" of pollution from energy use. Options capable of reducing harmful emissions even as energy production and use expands -- as it is bound to do in developing countries -- are available and are improving. Improvements in price efficiency and the management of energy resources offer scope for significant emission reductions, and have the added merit of reducing supply costs. But the decisive effect on abatement comes from interfuel substitution and technological change -- the substitution of gas for coal where it is abundant, the use of clean coal combustion and emission control technologies, the use of low sulphur or desulfurized fuels, in the use of unleaded fuels and catalytic converters on vehicles, in the substitution of commercial fuels for fuelwood, and in several other ways. Figure 7 demonstrates these conclusions using a simulation study of prospective emissions from electric power generation in developing countries under alternative assumptions. (Similar results are obtained when emissions from transport, industry and domestic fuels are similarly studied.) It contrasts emissions (a) when no abatement measures are in place with (b) the reductions when there is rising managerial and price efficiency, and (c) when abatement technologies are introduced.

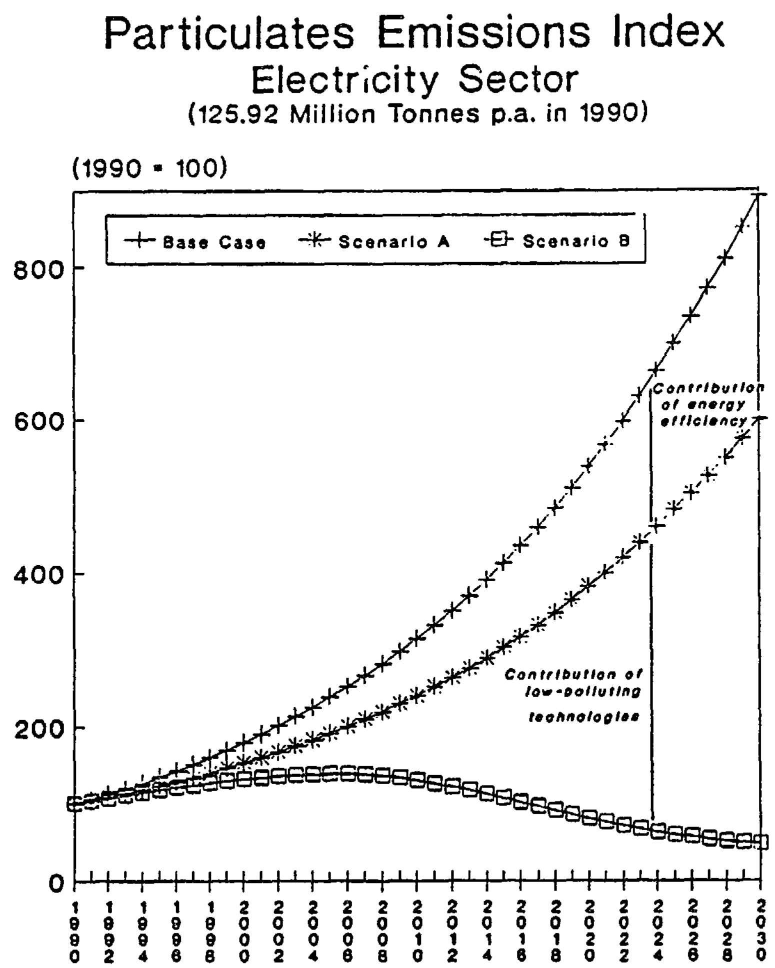
• Lags. Given the time required to introduce policies and for abatement methods to be incorporated into the capital stock, pollution can be expected to intensify seriously before it is abated, even when aggressive policies are in place. The high growth of energy demand further amplifies this effect.

• Costs and benefits. The extra costs of introducing low polluting technologies and fuels can sometimes be large in absolute terms. However:

(i) They are generally small in relation to the overall supply costs of energy--typically 5 percent or less;
(ii) The efficiency gains from advanced combustion and energy conversion technologies may often lead to cost reductions, and;
(iii) Approximate estimates of health benefits, even neglecting many welfare intangibles, show that in more polluted regions, additional expenditures often have good economic rates of return.

• The gains from energy efficiency. Economic losses due to inefficiencies in energy production and use are substantial. Two sources of inefficiency - subsidies and managerial inefficiencies of various kinds - result in losses amounting to perhaps 30 or 40 percent of supply costs in many regions. A combination of energy efficiency and pollution abatement policies would therefore reduce costs and pollution.

Figure 7 Scenarios of long-term emissions from electricity generation in developing countries



Notes: Base Case: No controls on emission.
Scenario A: No controls but with improvements in price and managerial efficiency.
Scenario B: With controls and efficiency improvements.

IV. GLOBAL WARMING

If it becomes necessary to restrict the use of fossil fuels on account of the global warming problem, will noncarbon technologies become available to meet the world's demands for commercial energy? What would be their costs? And what would be their impact on economic growth? Analysis of the available options shows that far from presenting the world's societies with insuperable problems, the challenge of reducing CO_2 emissions and accumulations is leading to new opportunities to solve old problems in an environmentally and economically desirable way.

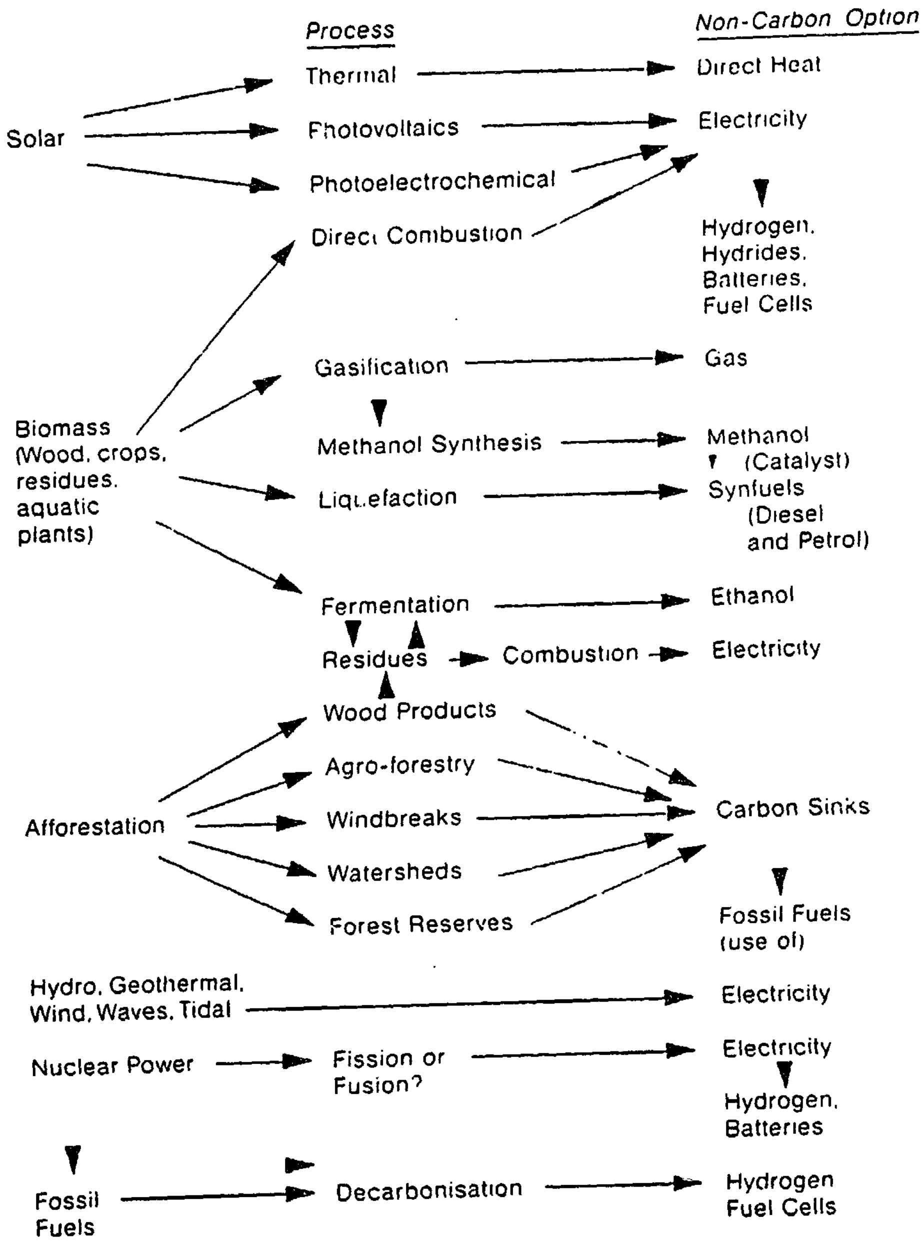
1. Nuclear and Non-nuclear Options

Too often, discussions of the global warming problem proceed as if there were no economically or operationally feasible substitutes for fossil fuels, other than nuclear energy. However, there is appreciable public and private R&D activity into such substitutes, primarily renewables. High oil prices from 1973 through 1985 stimulated much commercial research into nuclear energy, solar energy from photovoltaics and thermal-collector (thermal-solar) schemes, hydrogen fuels based on these resources, the use of biomass for electricity generation, and the production of liquid fuels such as ethanol and methanol, again from biomass. Figure 8 summarizes some options. Although economic interest in these declined after the collapse of oil prices in 1985-86, it is evident that a range of backstop technologies are emerging, at prospective costs not far removed from those of fossil or nuclear fuels -- perhaps lower once environmental factors are taken into account. In theory, nonfossil fuel energy resources are capable of meeting all the world's energy demands over the long term.

Since the 1950s, nuclear energy has widely been regarded and planned for as the main backstop technology, should fossil fuels should become scarce. However, initial estimates of fossil fuel reserves, on which nuclear R&D programs were premised, have proved to be very cautious. The world's proven reserves of oil in 1950 stood at 100 billion barrels (Bboe); by 1970 they had risen to 550 billion barrels and by 1990 to over 1,000 billion barrels, notwithstanding a total world consumption of nearly 600 billion barrels over the 40 year period. Proven reserves of coal and natural gas also rose remarkably. However, proven reserves tend always to be estimated conservatively; they are generally defined as those quantities which geological and engineering information indicate with reasonable certainty as recoverable from known reservoirs or deposits under existing economic and operating conditions. Recent estimates of "ultimately recoverable reserves" are about six times the above figures in aggregate (see Table 11, right hand column), or about 650 times current annual rates of extraction. Allowing for continued demand growth in the developing countries and for some conservation in industrial countries, fossil fuel resources are probably sufficient to meet world energy demands for the next one to two centuries, perhaps longer.

Increased knowledge of the extent of fossil fuel reserves, together with technical progress and cost reductions in extraction methods, have greatly undermined the role of nuclear energy as a backstop technology -- quite apart from the environmental problems that have arisen with

Figure 8 Technology Options for Reducing Carbon Accumulations



The figure does not include a perhaps longer list of options relating to substitutions and efficiency improvements on the energy demand side and improvements in conversion efficiency technologies (e.g. in the efficiency of thermal power stations)

Table 11 World oil, coal and gas reserves and consumption, 1950-90 (Bboe)

	Proven Reserves 1950	1970	1990	Consumption 1950-90	Ultimately recoverable reserves
Coal			4200	500	20,000
Oil	100	550	900	600	2,000
Natural Gas		250	900	250	1,500
Shale oil and tar sands				small	10,000

Sources: UN Energy statistics. BP Statistical Review of World Energy (1990), and Shell Briefing Service No. 2, 1987.

the latter. Will concerns about the greenhouse effect restore its role?

Although its economic attractiveness would increase relative to fossil fuels if regulations or taxes were introduced on carbon emissions, the operational feasibility of substituting nuclear energy for fossil fuels on a large scale should be questioned on two grounds: environmental risk, and resource limitations (including human resources and skills). Raising nuclear's contribution to world energy supplies to one-quarter over the next four decades, would require the construction of several thousand large (1,000 MW) nuclear stations in developing countries; at present, this is not an operational possibility.

Whatever the future role of nuclear fission or fusion energy, other forms of noncarbon or backstop technologies will also be needed on a substantial scale if it becomes necessary to limit the level of atmospheric CO_2 accumulations. Two possibilities hold enormous promise, namely solar energy and biomass. Secondary renewable resources include hydro, geothermal and wind.

2. Solar energy

Although solar is a diffuse source of energy, the areas required to supply commercial energy from solar sources on a large scale are small in relation to the land available. In developing countries, total solar insolation is about 10,000 billion tonnes of oil equivalent energy per year (120,000 TWh), or roughly 6,500 times their annual consumption of commercial energy. Modern photovoltaic (PV) schemes can convert 7 to 20 percent of solar insolation into electrical energy, depending on materials used and cell design, while efficiencies for future advanced systems are projected at over 30 percent. Solar-thermal schemes already have conversion efficiencies of over 20 percent, and have potential efficiencies of over 30 percent. At conversion efficiencies of 15 percent, less than 0.1 percent of their land area would theoretically be required to meet the whole of developing country energy requirements from solar resources; less than 0.05 percent, if improvements in conversion efficiencies are allowed for and schemes are situated in high insolation areas.

Land intensities are also low relative to hydro (see the examples in Table 12). At current conversion efficiencies, intensities are less than one hundredth of those for large hydro schemes (eg. Akosombo in Ghana, and the Aswan/High Dam in Egypt), and around one-tenth of those for hydro projects with good heads and favorable energy output-to-reservoir area ratios. Furthermore: (a) the ideal locations for solar schemes are often arid areas with small populations; (b) site choice is sufficiently flexible to minimize -- or avoid altogether -- competition for land in arable or forested areas and the displacement of populations[28], and; (c) the land occupied by solar collectors (whether PVs or thermal) need not be lost to production, and can in principle be used for agriculture or other purposes -- a subject of much research and experimentation.

Table 12: Land Intensities of Hydro and Solar Projects

Scheme	MW	GWh	Km^2	GWh/Km^2
Hydro				
Akosombo, Ghana	970	4,700	8,500	0.6
Victoria, Sri Lanka		465	24	28
Karakaya, Turkey	1,800	7,353	300	25
Aswan/High Dam Egypt		9,560	5,180	1.8
Solar Schemes				
(in High Insolation Areas):				
Insolation 2000 Kwh/m^2 = 2000 GWh/Km^2				
Conversion at 15% efficiency = 300 GWh/Km^2				
Allowance for spacing (50%) → 150 GWh/Km2				

Solar energy is therefore a resource that could be harvested on a very large scale with negligibly small claims on land resources -- indeed it could put hitherto unused areas to productive use. Costs are the main issue.

In this respect, remarkable developments have taken place over the past two decades. In 1970, PV units cost about $200,000 per peak KW of capacity (KWp) in 1989 prices, and applications were largely confined to aerospace programs and other specialized uses; by 1980, costs had fallen to the $25,000-50,000 range, and by 1990 another five to eightfold decline had occurred. Costs for grid-tied systems are currently about $6,000/KWp. The US Department

[28] Because the technology is modular, dispersed small scale units can also be contemplated for PV systems.

of Energy has projected costs of $2,100/KWp by 2,000 falling to $1,500/KWp a decade later, and $1,000/KWp in the long-term. In high insolation areas this would put generation costs at between 4 and 6 cents per KWh, and would make solar schemes competitive with fossil fuels and less costly than nuclear power, even without taking account of environmental factors.

Costs have fallen, and will continue to fall, for two main reasons:

- Scale economies and technical progress in production. World output rose from under 5 MWp/year in the early 1980s to 50 MWp in 1990. This is still very small; a larger market would enable manufacturers to reorganize production and introduce large scale manufacturing techniques that would bring about significant cost reductions.
- Further improvements in conversion efficiencies. Current efficiencies are between 7 and 20 percent, depending on cell type and the quality of material used; efficiencies of over 30 percent are feasible. The use of (multi-junction) devices to capture higher proportions of the solar spectrum is another area of rapid progress.

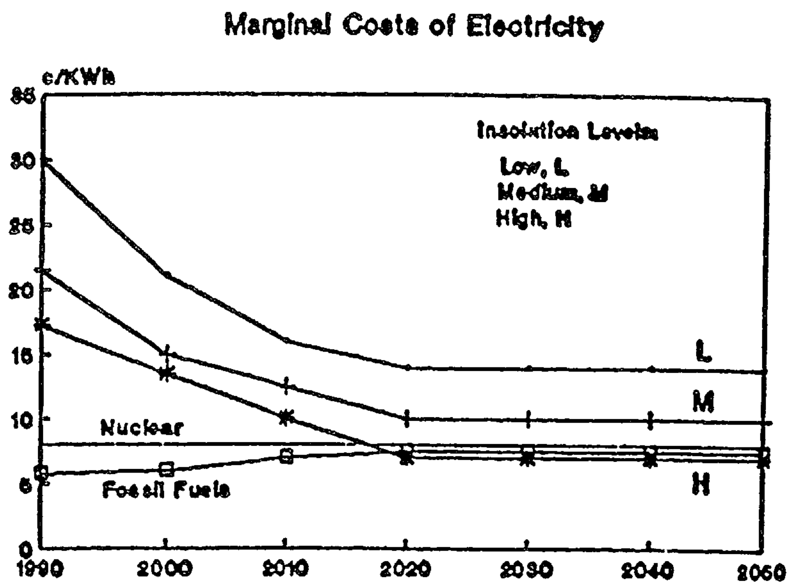
Progress in solar-thermal schemes has also been remarkable; conversion efficiencies in excess of 20 percent are already being achieved, with generation costs now below 10 cents/Kwh. Figure 9 shows one long-run cost scenario for solar schemes, compared with fossil-fired and nuclear plants. The figures allow for storage costs, and are based on a mix of photovoltaic and thermal-solar schemes.

3. Biomass

Biomass (mainly wood) fuels are still the primary source of energy in many developing areas; they are used mainly for cooking and heating, as they were historically in industrial countries. The great attraction of biomass, should it become necessary to restrict the use of fossil fuels, is the diversity of energy needs it can serve: electricity generation, and the demands for gaseous and liquid fuels, including synthetic gasoline and diesel fuels as well as ethanol and methanol. The technologies are well proven, and there is scope for further technological advance and for economies of scale, both of which would reduce costs further. Another attraction is that it is a form of stored energy, and can thus be used as and when needed.

The experiences of Brazil and the United States with ethanol programs indicate costs of between $75 and $100 per barrel of oil equivalent energy, although engineering studies of advanced processes and higher yield plantations suggest that costs of $60 per barrel (or less) may be achievable in the long run. Costs may thus be typically $20 to $40 per barrel higher than long-term ex-refinery costs of oil fuels, depending on price assumptions for the latter, and the long-term costs of synthetic liquid fuels from coal, tar sands and oil shale. Using biomass to substitute for oil fuels on a large scale would therefore add significantly to energy costs -- assuming no further advances in conversion technologies. What can be said at present is that, if necessary, a proven backstop technology for the liquid fossil fuels market is available.

Figure 9 A long term cost-scenario of electricity generation from solar energy in high insolation areas, and from fossil fuels



For electricity generation, the costs of biomass fuels relative to fossil fuels are much more favorable, partly because more of the biomass is utilized, but also because electricity is a higher value added market (generation costs of 5 cents/Kwh, a typical OECD figure are equivalent to $80/barrel in oil equivalent energy units). The United States alone has over 9,000 MW of biomass-fired power stations, though costs are higher than for fossil fuels. However, recent engineering studies of new high efficiency generation technologies using gasified biomass in combined cycle power plants[29] have shown that costs of between 4 and 6 cents/KWh are feasible, which in many regions would make such schemes competitive with fossil fuels.

Land intensity, however, is very large. The useful energy yield is typically 0.2 to 0.3 percent of the incident sunlight (less than one-fiftieth of the conversion efficiency of solar schemes). Although research has shown that biomass yields could be raised appreciably using higher yield species, any major expansion of biomass programs would ultimately place significant pressures on land resources and land prices. This in turn would raise the economic incentives to complement biomass fuels with solar derived hydrogen energy or further electrification of the energy markets.

4. A renewable energy scenario

Suppose it becomes necessary to turn to renewable energy on a large scale. The fossil

[29] Booth and Elliott (1990), Shell Selected Papers.

fuel industry is very large and its investments have long lead and lifetimes (typically forty years from "cradle to grave"); end use technologies and consumer appliances - in industry, transport, commerce and homes - would need to be adapted or changed to accommodate new energy sources. Even assuming rapid expansion of the industry, it would take renewables two or three decades to become a significant global competitor to fossil fuels. How long would it take to effect a transition to a low net-CO_2-emissions scenario, and what would that transition cost?

Figure 10 presents one such scenario. It assumes fairly rapid development of the renewables industry, and a rising degree of energy efficiency in all regions. The share of gas in total fossil fuel supplies is assumed to rise over the long-term, and investments in hydro and nuclear power take place at roughly present rates. Three conclusions emerge from analyses of this kind, and are well supported by economic and engineering research:

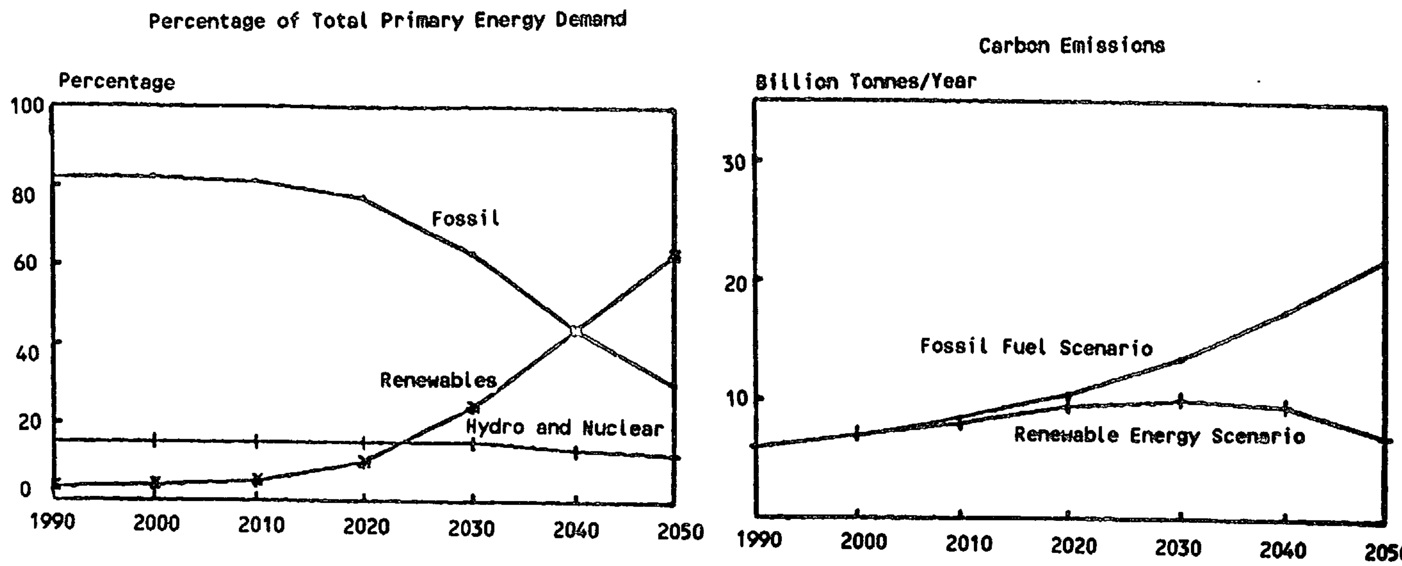
(1) The large scale substitution of renewables for fossil fuels is a practical possibility, and net CO_2 emissions from energy consumption could be stabilized over the long term (see Figure 10, lower curve).

(2) However, time-lags are very long given that the industry would have to develop from a small base and that the demand for commercial energy is rising rapidly in developing countries. The use of fossil fuels would likely double (under an energy efficient scenario) in the decades immediately ahead, before peaking and declining, and there is thus the danger that global CO_2 accumulations might exceed safe levels in the intervening period. This risk of course adds to the importance of precautionary policies being put in place.

(3) In the tropics the costs of electricity generation would likely be <u>reduced</u> in the long term. Since the share of electricity in total primary energy consumption has already risen to over 30 percent in developing countries (it is 40 percent in the industrial countries), and may reach 50 percent or more, this would constitute a sizeable benefit. But for non-electric markets (primarily oil and gas), the extra costs of substitution might rise to $30/boe, or 70 cents/gallon of oil equivalent energy. Such costs might be reduced by technical progress, and would also tend to stimulate further electrification of energy markets). Nevertheless, when multiplied by the size of the nonelectric energy markets, they imply substantial increases in energy costs.

Moreover, higher costs would, in all probability, <u>not</u> have a calamitous effect on growth and development. For the next three decades, simulation studies show the impact on economic growth averaging less than 0.05 percentage points (see Figure 11), even ignoring the possibility that the costs of backstop technologies could fall faster than in the scenarios presented above. The reasons for these small growth effects are: (i) the technologies would ideally be phased in gradually, and shocks avoided; (ii) the marginal cost curves fall steeply with investment; hence costs are high when investment levels are low, but relatively low when investment levels are

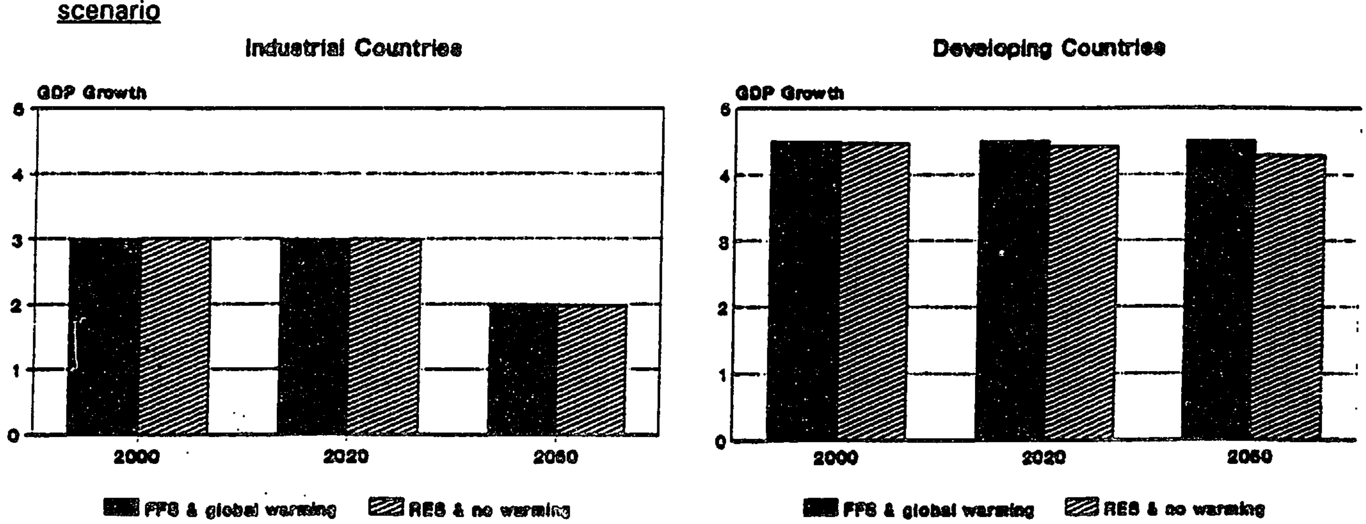
Figure 10 The renewable energy scenario revisited



Explanatory Notes

The possibilities for substituting renewable energy for fossil fuels date back at least a century. In 1891, Rollo Appleyard was so enthused by solar cells developed by Sir George Minchin in London, that he wrote, in a letter to the editor of the Telegraphic Journal and Electrical Review, "Behold the blessed vision of the sun, no longer pouring his energies unrequited into space, but by means of photoelectric cells and thermopiles, these powers gathered into electric storehouses, to the total extinction of steam engines and the utter repression of smoke". Quoted from Professor Hill's book, Photovoltaics. Hill (1990) adds that the "stunning technological advances of the past 15 years" have made this vision a practical possibility. Renewable energy scenarios were also studied extensively and shown to be operational by the energy industry following the oil price shocks of the 1970s and early 1980s. See van der Toorn (1987).

Figure 11 Impact on economic growth of the higher energy costs of moving to a low carbon emissions scenario

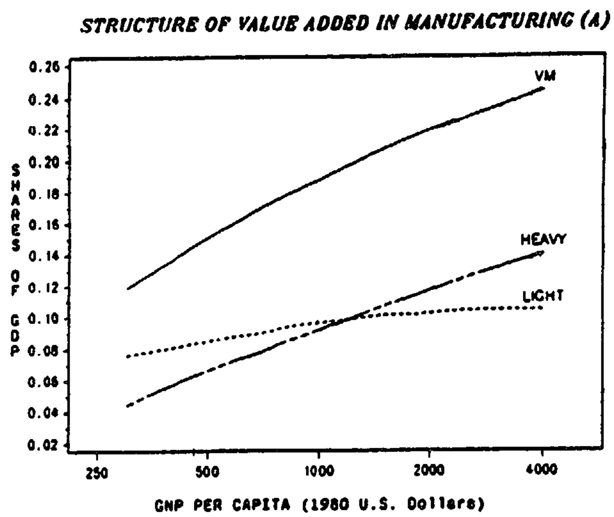


high; (iii) the growth of the world economy would leave both developing and industrialized economies better placed to finance the extra costs. Scientific evidence is insufficient for a reliable assessment of the effects of global warming on economic growth under the fossil fuel scenario. What can be said however, is that the costs of introducing precautionary policies in the next ten to twenty years that would leave future generations better placed to avert global warming, would not be prohibitively high.

V. INDUSTRY

Industrial output in developing countries presently amounts to about $1,200 billion per year, or 38 percent per cent of their total GNP. For the past twenty-five years, industry's share in total economic output has been rising: from 20 to 27 percent in Sub-Saharan Africa, from 33 to 44 percent in East Asia, from 21 to 26 percent in South Asia, and from 33 to 35-40 percent in Latin America. Declines have occurred in some periods in some countries (for example Argentina, Ghana and Tanzania) as a result of economic instability and restructuring, but the overall rise in industry's contribution to output as economies develop is now well documented. Rising demands for nonfood goods and services as per capita incomes increase, growing developing country participation in world trade and manufacturing investment, and backward linkages from agriculture and infrastructural services, are some of the factors behind urban-industrial expansion. Figure 12 summarizes the results of some well-known research on the subject; it shows the growth in the shares of value added in light and heavy manufacturing, and of industry in total, as per capita incomes rise. A combination of growing populations and per capita incomes will probably double industrial output in developing countries in the present decade and quadruple it in the next two. It also provides employment and earnings opportunities for 1 billion people today rising perhaps to 2 billion by 2010.

Figure 12



Light manufacturing includes food, beverages, tobacco, textiles, clothing, wood and wood products, paper and printing. Heavy manufacturing includes chemicals, minerals, metal, and machinery. The industrial totals [to be added to the top curve] include electricity, utilities, mining and construction.

Source: Syrquin and Chenery (1989)

1. Nature of the Industrial Pollution Problem

The problem for developing countries will be how best to reap the benefits of increased urban-industrial activity, while reducing environmental side-effects to socially acceptable levels. With few exceptions, industrial pollution in developing countries is becoming more intensive and more complex. Corrective policies are rarely in place:[30]

Air pollution. Principal pollutants include particulates, sulphur dioxide, carbon monoxide, nitrogen dioxide, ozone, and toxic pollutants such as benzene, vinyl chloride, hydrogen sulphide, and other toxic gases.

Water pollution. The discharge of industrial effluents (for example, heavy metals, organic and inorganic chemicals, oil, suspended solids, and nutrients) into water bodies without treatment or pre-treatment, reportedly occurs in numerous cities. Although little information is systematically collected (itself an issue for policy), waste discharges are reported as substantial. Mercury contaminated wastes have been discharged into water bodies in Bangkok, Perai (Malaysia), Bombay, Managua, Alexandria, Cartagena and several Chinese cities. In Mexico, it is estimated that industrial effluents account for 90 percent of total water pollution, and in Columbia 50 percent. Problems of surface water pollution are further compounded by the discharge of untreated sewage and the dumping of solid wastes into rivers (see Box 7).

Groundwater pollution. A range of urban, industrial, agricultural and mining sources threaten ground water quality. The main sources of pollution include unsewered sanitation, leaking sewers, sewage land discharges, leaching refuse dumps, leaking industrial storage tanks and pipelines, industrial water effluent lagoons and land discharges, leaching industrial waste disposal sites, agro-chemicals, and drainage water and other discharges from the mineral extraction industries. Although the extent and severity of pollution are unknown, it is visibly serious.

In Latin America, it has been estimated that the leachate from solid waste landfills is rising at 4 percent per year (solid waste production is presently 60 million tonnes per year).[31] A recent study commented that "the leachate from sanitary landfills usually contains high concentrations of both organic and ammoniacal nitrates, copper, zinc, nickel, phosphates, sulfates, chlorates, CO_2, SO_3, etc. and is characterized by high pH and extremely high BOD (20,000-30,000 mg/l, [hence] the risk to the region's ground-water resources is significant. Moreover, industrial wastes are generally dumped together with domestic wastes (ECLAC 1989). In some cases, industrial effluents are discharged directly into ground water. In Mexico, for example, a company was forced to close after it was discovered to have been pumping highly toxic chromium wastes into the aquifer in the Mexico Valley area, threatening the water supply

[30] See Janis Bernstein's study (Draft, June 1991) from which the following is extracted.

[31] Bernstein (1991)

Table 13 Manufacturing industries and associated hazardous wastes in industrializing countries

INDUSTRY	HAZARDOUS WASTE PRODUCED
Metal finishing, electroplating, etc.	Heavy metals, fluorides, cyanides, acid and alkaline cleaners, abrasives, plating salts, oils, phenols
Leather tanning	Heavy metals, organic solvents
Textiles	Heavy metals, toxic organic dyes, organic chlorine compounds, solvents
Oil, gasoline & basic petroleum products	Oil, phenols, other organic compounds, heavy metals, ammonia salts, acids, caustics
Pesticides	Organic chlorine compounds, organic phosphate compounds, heavy metals
Pharmaceuticals	Organic solvents and residues, heavy metals (especially mercury)
Plastics	Organic chlorine compounds
Paints	Organic solvents and residues, organic pigments, heavy metals (especially lead and zinc)

Source: Leonard (1986)

of nearly 20 million people (Leonard 1986)."[32]

Hazardous wastes. Although chemical and petrochemical industries are the source of most hazardous wastes, other sources such as primary and fabricated metal and industries, petroleum refining, pulp and paper, mining, electrical equipment industries and pharmaceuticals also produce significant quantities (see Table 13). It is also reported that the environmentally unregulated "development of small-scale manufacturing that generate[s] hazardous wastes in small quantities is a growing problem ... The location of many such enterprises in [densely populated] low-income neighborhood results in the exposure of local populations to high concentrations of hazardous waste."[33]

Before turning to the question of whether, once policies are in place, such technically and economically complex problems are manageable, three further aspects of industrial pollution in developing countries need to be emphasized. The first is that, with rare exceptions, policies are either not in place or, where they are, compliance is poor. This helps explain current concern

[32] Ibid.

[33] Ibid, p28.

Box 7: Water pollution problems in selected cities

KARACHI: The Lyari River which runs through Karachi is an open drain from both chemical and micro-biological points of view; a mixture of raw sewage and untreated industrial effluents. Most industrial effluents come from an industrial estate with some 300 major industries and almost three times as many small units. Three-fifths of the units are textile mills. Most other industries in Karachi also discharge untreated effluents into the nearest water body.

BOGOTA: Many tanneries and plastic processing plants pour untreated wastes containing lead and cadmium into the Tunjuelito, a tributary of the Bogota River. The result is a high degree of pollution and the dissolved oxygen in the water is almost depleted.

ALEXANDRIA: Industries in Alexandria account for about 40 percent of all Egypt's industrial output and most discharge liquid wastes, untreated, into the sea or into Lake Maryut. In the past decade, fish production in Lake Maryut has declines by some 80 percent because of the direct discharge of industrial and domestic effluents. Similar environmental degradation is occurring along coast as a result of the discharge of untreated waters from poorly located outfalls. The paper, textiles, and food industries are the principal contributors to the organic load.

SHANGHAI: Every day some 3.4 million cubic meters of industrial and domestic waste pour mostly into the Suzhou Creek and Huangpu River which flows through the heart of the city. Most of the waste is industrial because most houses do not possess flush toilets. The Huangpu may be the most heavily polluted stream in the world; essentially dead since 1980. It is a chemical cocktail of raw sewage, toxic urban wastes, and huge volumes of industrial discharges. A high water table means that a variety of toxins from industrial plants and local rivers find their way back into ground water and contaminate wells which also contribute to city water supplies.

SAO PAULO: Two main rivers are completely dead; most residential sewage and industrial effluent flows directly into rivers and other water reservoirs. Studies by CETESB have shown that over 60 percent of the fish in the Tiete and Piracicaba Rivers in the Sao Paulo metropolitan area have mercury levels above the limits considered safe (0.5) and that 80 percent of fishermen and their families who live near these rivers have elevated mercury levels. In southern Sao Paulo, CETESB detected lead levels over 70 times higher than the allowed limit in the Ribeira de Iguape River, which is an important source of drinking water in the area.

Source: Hardoy and Satterthwaite (1989) and Briscoe (1989). (Taken from Janis Bernstein (1991).)

over the environmental consequences of industrial expansion in the Third World, the "dumping" of hazardous wastes, and the migration, via trade and investment, of "dirty" industries to these regions (see Box 8).

A second aspect concerns the dangers of a buildup in the pollutant stock.[34] Rates of emissions, effluents and wastes, expressed in per annum terms, present a very misleading picture because such wastes have long lifetimes. Industrial country experience indicates that the costs of prevention are frequently far lower than those of clean up, even when estimated according

[34]See David Wheeler (1991)

to the demanding arithmetic of discounted cash flow. The United States, for example, after a century of unregulated industrial disposal, now faces an enormous treatment cost for buried hazardous wastes. According to a recent estimate by the U.S. Office of Technology Assessment, at least 10,000 burial sites will ultimately be considered dangerous enough to require cleanup under the Superfund Act. Tietenberg (1988) argues that it will be neither technologically nor economically feasible to clean up more than 20% of such sites during the next few decades.

The third aspect concerns the growing technological complexity of pollution, which is afflicting the developing countries at a far earlier stage of industrialization than it did in the industrialized countries. At a recent symposium on hazardous wastes organized by the American Chemical Society, it was noted that since World War II waste management problems have been exacerbated by two factors -- quantity and toxicity. Waste quantities have steadily increased due to population growth and because waste generation per man, woman and child continue to increase (especially in the US). Wastes are also increasingly toxic and exotic. Radioactive wastes, for example, were virtually non-existent before World War II. Similarly, industrial wastes from solvent use, electrochemical applications, paints, spent industrial catalysts, biochemicals, fertilizers and pesticides, to name a few, all result from recent technological

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Box 8: Export of hazardous wastes

BANGKOK: Large quantities of chemical wastes have been stored in Bangkok's main port, Klong Tuey. Most came from unknown shippers in Singapore although some also came from the United States, Japan, West Germany, and Taiwan. Officials from the government's National Environment Board have expressed fears that the barrels may contain PCBs or dioxin which can only be destroyed in high temperature incinerators which Thailand does not possess.

BENIN: European firms were seeking a contract to send five million tons of waste each year from Sesco, a company registered in Gibraltar. It was reported that Benin was to receive $2.50 for each ton received while Sesco would charge firms up to $1,000 or more to dispose of the wastes. Benin is one of the poorest nations in the world and lacks virtually all of the infrastructure and the government system needed to handle and manage even a small fraction of the five million tons a year proposed.

GUINEA: A Norwegian firm dumped some 15,000 tons of burnt or partially burnt industrial waste and incinerator ash from the United States and Norway on the island of Kassu, near the capital of Conakry.

NIGERIA: Three thousand tons of European chemical wastes were dumped by Italian ships in the southern port of KOKO on the Niger river with a payment to the landowner of the equivalent of around $100 a month; the cost of disposing of these in Europe would be of the order of $350-1,750 a ton. The wastes are stored in 45-gallon (around 200-liter) drums, many of them leaking and most in poor condition. Many drums have volatile chemicals which in a hot climate, present a serious risk of a spontaneous fire or explosion.

Source: Hardoy and Satterthwaite (1989). Quoted from Bernstein (1991).

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innovations.[35]

Industrial chemicals' production is currently growing at about 7.5 per cent per year in developing countries versus 2.5 percent in developed countries (UNIDO, 1990). Growth is most rapid in Asia, where the increase of organic chemicals consumption (see Table 14) has stimulated ambitious plans for local capacity expansion (Vergara, 1990). In the absence of significant pollution regulation, the emissions intensity of this new production is likely to be even higher than in the United States.

Table 14 Domestic use of major Petrochemicals Asian region: annual growth percent in the 1980's

	Korea (80-88)	India (80-88)	China (82-87)	Thailand (80-87)	Malaysia (80-87)	Indonesia (81-87)
Ethylene	16.3	14.1	9.8	13.9	11.5	10.5
Propylene	12.3	14.0	12.2	13.0	10.5	7.5
Butadiene	2.3	--	15.9	40.0	-4.2	41.6
Benzene	13.4	14.2	11.7	12.6	--	5.6
Methanol	7.0	--	17.0	30.7	20.2	45.2

Source: Vergara (1990), Tables 2; 4; 6; 8; 10; 12. Quoted in Wheeler (1991)

2. Industrial Pollution Abatement: Technologies and Practices

As in other sectors of economic activity, there is no fixed relationship between industrial output and the level of industrial pollution and wastes. In important cases, rising output has been achieved while emissions and residuals have been reduced to low levels. Figure 13 shows the example of steel making in Germany, where dust emissions per unit output from pig iron and crude steel production were reduced by 70 percent and 90 percent respectively over a seventeen year period (1960 to 1977); emissions from modern iron and steel plants are now very low compared to those of forty years ago.[36]

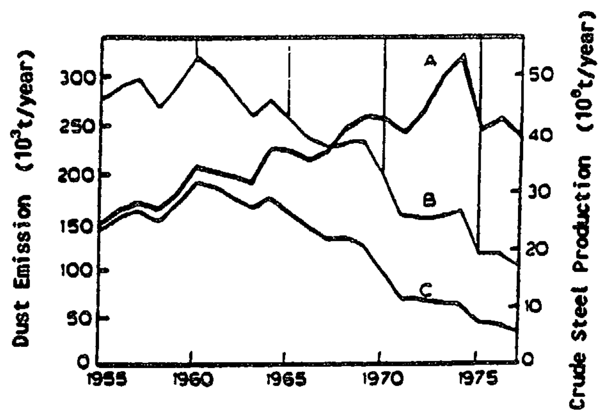
More generally, waste flows may vary widely between firms in the same industry due to differences in production methods, the quality of "housekeeping", water reuse, and the extent of inplant recycling of materials and wastes -- all depending, it should be added, on local regulations and laws regarding emissions and wastes. Table 15 shows the results of one survey of US firms in five industries; for the low polluters, effluents and wastes were only small

[35] Tedder and Pohland (1990) (Editors), Emerging Technologies in Hazardous Waste Management, American Chemical Society, Washington D.C.

[36] Suess, Grefen and Reinisch (1985). Ambient Air Pollution from Industrial Sources: A Reference Handbook.

fractions of those of the high polluters.

Figure 13 Crude steel production and dust emissions in Federal Republic of Germany (1955-77)



A, crude steel production
B and C, dust emissions from pig iron and crude steel production, respectively

Source: Suess, Grefen and Reinisch (1985), p351.

Table 15 Variations in flow and waste characteristic among firms in selected United States industries.

Industry	BOD, gallon/production unit, % frequency			Suspended Solids, lb/production Unit, % frequency		
	10	50	90	10	50	90
Pulp and Paper[a]	17	58	100	26	105	400
Paperboard[a]	10	28	4	25	48	66
Slaughterhouses[b]	3.8	13	44	3	10	31
Breweries[c]	0.8	2	44	0.25	1.2	2.5
Tanneries[d e]	575	975	1400	600	900	3200

[a] tons of paper
[b] 1000 lb live weight
[c] bbl beer
[d] pounds of hides
[e] In the case of tanneries, water wastes are measured as mg/l.

Source: Eckenfelder (1989) Industrial Water Pollution Control (Table 1.2).

There are two broad means of reducing industrial pollution to acceptably low levels -- waste treatment, and waste minimization or prevention through changes in processes or raw materials used. Combinations of the two are common.

Waste treatment processes. These are sometimes referred to as "end-of-pipe" technologies, and are to be found in practically every branch of industry where environmental policies place limits on pollution. Examples for air pollution include electrical and mechanical methods for removing dust particles from industry furnace exhausts, and the flue gas desulphurization and NO_x reducing technologies discussed above (for electricity generation). Mechanical and chemical methods are also available for the treatment of contaminated water wastes. For hazardous wastes, the Standard Handbook of Hazardous Waste Treatment and Disposal,[37] provides a comprehensive assessment of approaches under five headings: (i) Waste minimization (discussed below); (ii) Chemical processes for recovering materials of value from waste streams; (iii) Physical and chemical treatment, for either volume reduction (concentration), detoxification or stabilization; (iv) Thermal processes, designed to break down hazardous waste through combustion or pyrolysis (chemical changes induced by heat) by exposing the material to high temperature in a controlled environment (the Handbook notes that thermal processes "can in a matter of seconds, destroy waste materials that might otherwise take many years to deteriorate in a landfill"); and (v) Biological processes. These latter "have been used for many years to treat municipal and industrial wastewater. Many of the advantages of biological processes translate equally well to selected hazardous waste streams."

Waste minimization and pollution prevention. A frequently raised objection to end-of-pipe processes is that they do not actually reduce the amount of pollution, but merely concentrate it into a seemingly more manageable form; when the pollutant is concentrated and disposed of, it may later leak and contaminate soil and groundwater sources. While this has unfortunately been true in a large number of instances in industrial countries, waste treatment processes do frequently reduce waste quantities (e.g. by recycling) or neutralize its toxicity by chemical or thermal methods. Nevertheless, concerns have prompted a flurry of developments in the area of waste minimization and prevention. Possibilities are numerous, and have been reviewed in a large number of studies.[38] They include: (i) reformulating products or processes to contain or use less hazardous raw materials; (ii) on-site and off-site recycling, e.g. of treated wastewaters and materials; (iii) segregation of hazardous from non-hazardous wastes (which facilitates the treatment of the former, and the re-use of both); and (iv) a range of operating procedures, normally coming under the heading of "good housekeeping", which have been found to be environmentally and economically effective when incentives are in place -- reductions in leaks and spills, good maintenance practices, and so forth. Table 16 shows the results of a German study of the potential for reducing domestic hazardous wastes by these means.

Aside from its potential for reducing pollution, the low-waste-and-prevention approach has in several instances been found to reduce costs relative to conventional waste treatment technologies.[39] Why then is the approach not more widely adopted? In part, it is; on-site

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[37] Prepared by the US EPA Hazardous Waste Engineering Research Laboratory. Editor: Harry M. Freeman. McGraw-Hill.

[38] OTA(1987) Serious Reduction of Serious Wastes UNIDO (1990/91) Industry and Development: Global Report (pp148-158). Freeman (1988) Standard Handbook of Hazardous Waste Treatment and Disposal, United Nations ECE (1981) in 4 volumes: Compendium on Low and Non-Waste Technology, and OECD (1991) The State of the Environment.

[39] For a review of various industry and government reports, see UNIDO (1991).

Table 16 Waste reduction potential through low-waste practices (Germany)

	1983 Amount (million tones)	Waste Reduction Potential percentage
Sulfurous wastes (acids, gypsum)	2.2	80
Waste emulsion	0.5	40-50
Dyes and painting residues	0.3	60-70
Solvents	0.3	60-70
Galvanic sludges	0.2	60-70
Salt slags	0.2	100
Other wastes	1.2	low
Total	4.9	50-60

Source: OECD (1991) p197.

recycling of water wastes, for instance, has been common practice in many industries for several decades. Part of the answer, however, is lags. The approach frequently requires the development of new substitutes for previously polluting materials and products, and sometimes basic changes in processes that cannot easily be incorporated into existing plant. (End-of-pipe technologies, in contrast, are often better suited to retrofitting.) Nonetheless, developments in this area are widespread, and are as well-suited to the needs of developing as of industrial countries.[40]

3. Costs, and lags in implementation.

With some exceptions, the costs of implementing pollution abatement practices in industry are not large relative to total investment and output. In the 1970s, investments in pollution abatement in industry averaged about 4 percent of industrial investment in the OECD countries, where pollution standards were even then much higher than they are currently in developing countries (see Table 17 for the United States and Figure 14 for Federal Republic of Germany). Costs have since risen to approximately twice these levels; first because of tightening standards, and second because of the rising costs of the clean up of toxic wastes that were discharged before satisfactory abatement policies were in place.[41]

Introducing industrial pollution abatement practices in developing countries would have only a small -- though possibly favorable -- impact on their rate of industrialization, but a large

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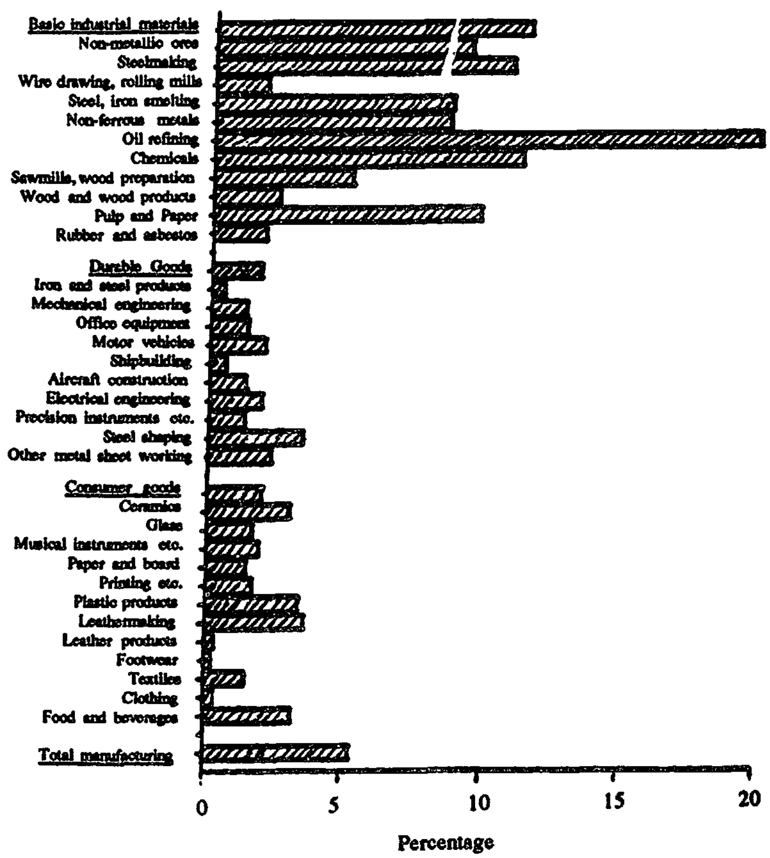
[40] US EPA (Dec.1990), "Environment Investments: The Cost of a Clean Environment."

[41] See annex for a summary.

impact on pollution (Figure 14). Neglecting the benefits of pollution abatement, higher investment costs of 5 to 7 percent might be expected to shave no more than 0.5 percentage points off industrial growth rates in most countries. Pollution levels, once the practices are incorporated into the capital stock, would be reduced dramatically. Allowing for the benefits, the long term impact on industrial would very likely be favorable: first, there would be health and amenity benefits for urban populations, and second, clean-up costs would be reduced. A transition to low pollution industrial policies would thus be in the economic interests of the developing countries. The main issue then becomes how best to bring this about.[42]

Figure 14 Industrial pollution control investment as a percentage of total industrial investment expenditure in the Federal Republic of Germany, 1971-77



Source: OECD, Environment and Economics (Paris, 1985).

[42] See Chapters 4, 5 and 7 of the World Development Report 1992.

Table 17 Expenditure for new plant and equipment by United States business and investments for air and water pollution control (1970)

	(1)[a] Total expenditure for new plant and equipment (billion dollars)	(2)[b] of which: for air and pollution control (million dollars)	(3) (2):(1) %
Iron and steel	1.83	17	99.8
Non-ferrous metals	1.10	41	3.7
Electric machinery	2.03	32	1.6
Other machinery	3.44	51	1.5
Motor vehicles	1.65	55	3.3
Aerospace }....		22	
Other transportation }	1.11	15	3.3
Stone, clay, glass	1.07	63	5.9
Fabricated metals }		44	
Instruments }....	3.74	25	4.6
Other durables }	—	103	—
Total durables	15.96	630	3.9
Chemicals	3.10	140	4.5
Paper and pulp	1.58	143	9.1
Rubber	1.09	9	0.1
Petroleum	5.63	280	4.6
Food and beverages	2.59	58	2.2
Textiles	0.63	10	1.6
Other non-durables	1.10	31	2.8
Total non-durables	15.72	651	4.1
All manufacturing	31.68	1,281	4.0
Mining	1.86	105	5.6
Electric utilities	8.94	155	1.7
Gas utilities	2.67	130	4.9
All other	30.40	presumably nil	-
All Industries	75.56	1,671	2.2

Sources:
a) "Survey of Current Business" (September 1970, p. 18).
b) "23rd Annual McGraw Hill Survey of Business Plans for New Plant and Equipment", cited in Hearings before the Sub-Committee on Air and Water Pollution, Committee on Public Works, U.S Senate, 91st Congress, Second Session (pages 390-391). Taken from a GATT study on "Industrial Pollution Control and International Trade," Geneva, July 1971. Studies in International Trade, No.1.

VI. AGRICULTURE

How far will the erosion and degradation of soils in agricultural regions impair the capacity of an expanding world population to feed itself? Given that damage to soils can be avoided by good soil management practices, and that such practices may even improve soil fertility, the question might usefully be stated another way: namely, what is the potential contribution of improved soil management practices to relieving environmental pressures in agricultural regions, and to raising net output in agriculture? The answer to this question also has a bearing on the protection of forests and wildlife, insofar as measures to raise and maintain farm yields reduce the land requirements of agriculture.

1. Food demands and supplies[43]

World cereal production and consumption (including coarse grains used for animal feed) rose by 90%, from approximately 0.9 to 1.7 billion tonnes, over the period 1965-1990, while the world's population rose from 3 to 5.3 billion people, or by 60 percent. In the developing countries cereal production rose by 90 percent (population, by 75 percent): the increases in Asia were 95 percent (population, 70 percent), in Sub-Saharan Africa 60 percent (population, 105 percent) and in Latin America 90 percent (population, 78 percent). These figures confirm the view, widely held by agriculturalists and economists, that despite the growth of the world's population, agriculture has so far had the capacity to meet the world's food needs; when shortages occur, as they do in parts of Africa and South Asia, they are almost invariably due to failures in trade and social and economic policy, or to civil strife, and are most tragically illustrated by the still widespread occurrence of malnutrition and periodic famines.

With the population of developing countries likely to rise from 4.1 to nearly 8 billion over the next forty years, access to agricultural output will need to double if per capita food consumption levels are not to decline; this mandates a growth rate of at least 1.5 percent to 2 percent per year. In the industrial countries, including the Soviet Union and Eastern Europe, per capita income is high enough that most people consume grain at close to the biological limit. In the United States, Canada and Western Europe, per capita grain consumption declined in the 1980s; in part, this is thought to have been a response to health concerns, which shifted consumer preferences from beef to poultry and fish, and thus decreased grain consumption.[44] But developing country per capita incomes, and their distribution, are such that many people are ill-nourished. This situation is likely to persist for a long time, with the result that the demand for grain (and, of course, for meat and dairy) will increase with population and per capita income growth. Per capita grain consumption in the developing countries is currently 250 Kilograms, compared with 350 Kilograms in Japan, 450 Kilograms in the European Community, and 850 Kilograms in the United States. Even with robust agricultural output growth of 2.5 percent per annum over four decades (leading to roughly a 2.5 fold increase in consumption), their per capita consumption would average just 350 kilograms/capita. These considerations lead to long-term demand projections for developing countries of around 2.5 percent per year, and for the industrial countries of about 0.4 percent per year, with production and consumption rising from around 1.9 billion tonnes today to over 3.5 billion tonnes in forty years' time.

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[43] All the following figures are preliminary only.

[44] Crosson and Katz (1991) and Crosson and Anderson (1991). The following remarks draw heavily on the latter report.

2. Land requirements and technical change

Until the 1950s, increases in agricultural production were highly dependent on more land being cultivated.[45] Since the 1950s, however, only Africa and Latin America have relied significantly on land expansion to raise output.[46] In Africa, approximately 40 percent of the growth in cereal production can be attributed to land expansion over the period 1961-1987, and 60 percent to yield increases. Corresponding figures for Latin America are 30 and 70 percent; for South Asia, 12 and 88 percent; for East Asia, 8 and 92 percent; for the OECD, 2 and 98 percent; and for the world, 7 and 93 percent. Thus the past three decades have seen the growth of agriculture become almost wholly dependent on the growth of yields (see Figure 15), and, by implication, on land resources being managed more efficiently.

Estimates of land potentially available show that agriculture's dependence on yield increases for growth will intensify over the coming decades, as populations and per capita incomes rise in the developing countries. The Food and Agricultural Organization (FAO, 1988) estimates that approximately 1.5 billion hectares were in crops in the mid-1980s, 3.25 billion in pasture and range, 4.0 billion in forests and woodlands, and 4.25 billion in wastelands, urban development[47], or otherwise not available for agriculture or forestry (see Figure 16). In principle, therefore, there is scope for further expansion of crop and pasture land through the clearance of forests and woodlands, or for economy in land use through the substitution of crops for pasture and ranching if (or as) dietary habits change. However, a recent review by Crosson and Anderson (1991) gives five reasons why future land expansion would raise relative costs; these reasons obviously provide further incentive for introducing land management practices and agricultural technologies in order to raise yields further.[48]

A. Quality of land. First, and as would be expected, agriculture is already located in areas where soils and climate are more favorable for production. Of the 1.5 billion hectares now classified as being arable or under permanent crops, roughly 60 percent or 0.9 billion ha are judged by agriculturalists to be in high and medium land capability classes. There are another 0.5 billion hectares similarly classified worldwide which are still not cultivated (some of which, however, may be under pasture), and another 0.4 billion hectares under forests (see Table 18). Since the total land used for agriculture, including livestock and ranching, now amounts to over 4.5 billion hectares, it is evident that much agricultural activity is on very

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[45] An exception was Japan, where limits to land availability and rising land prices stimulated a roughly three-fold increase in yields over the preceding eighty years. See Hayami and Ruttan (1985), Chapter 7.

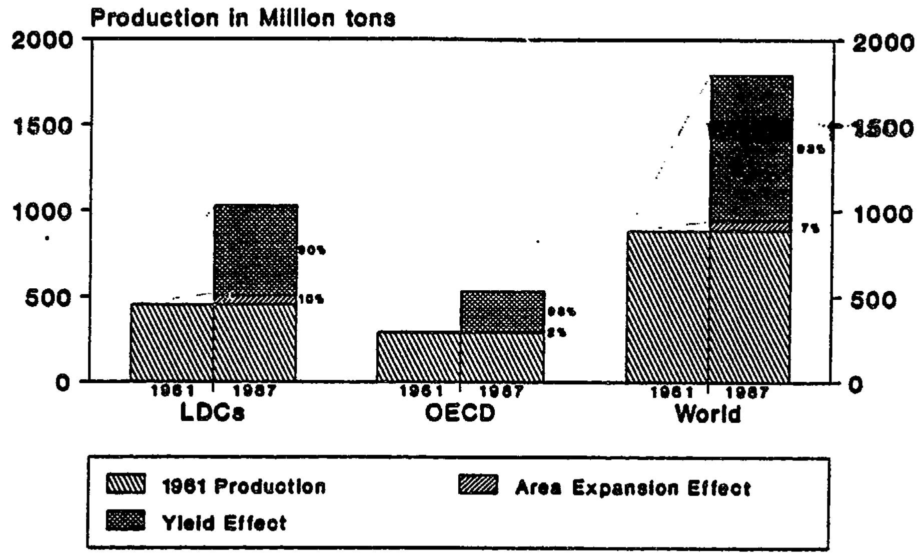
[46] Ranching activities have also expanded in these regions.

[47] Land occupied by urban areas in relatively small, about 0.12 billion hectares, assuming 0.05 ha/urban dweller. See Crosson and Anderson (1991, Chapter 3).

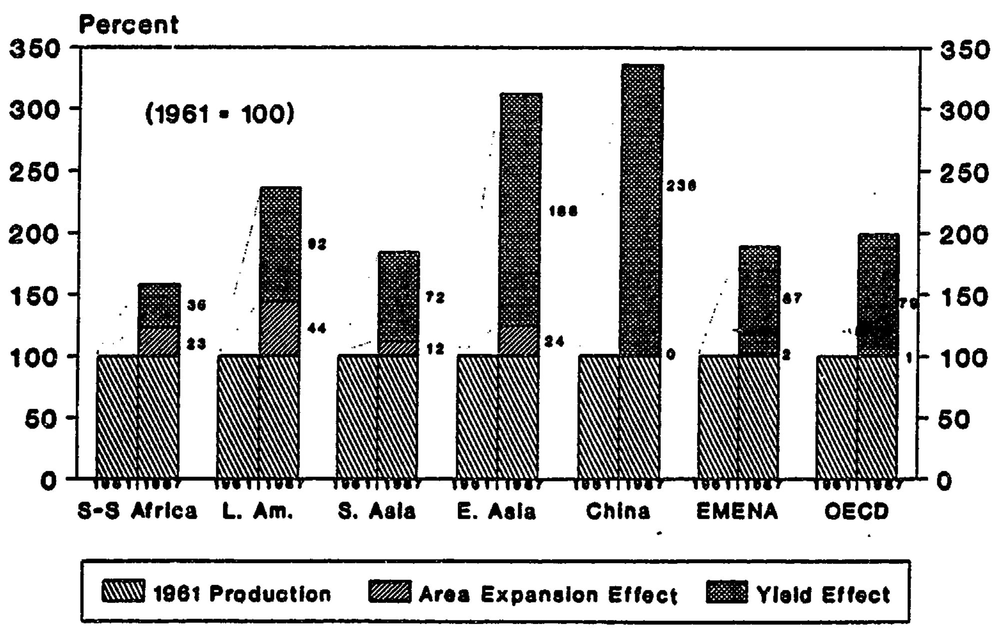
[48] The following remarks again draw extensively on the Crosson-Anderson report.

Figure 15 Yield and Area Expansion Effects, 1961 and 1987 (Cereals)

Production Change by Country Grouping



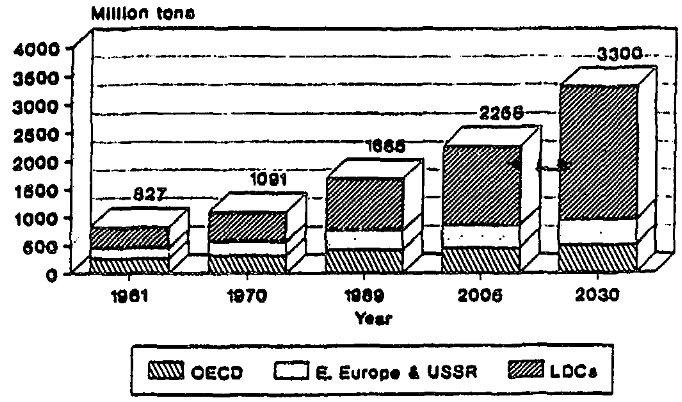
Percentage Change by Region



Note: East Asia figures exclude China.

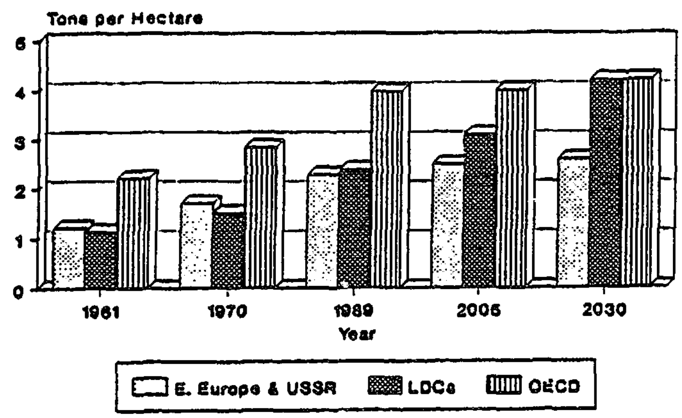
Figure 16 Grain Consumption; Yields; Yield and Area Effects

Grain Consumption
1961 - 1989 and Prospective to 2030



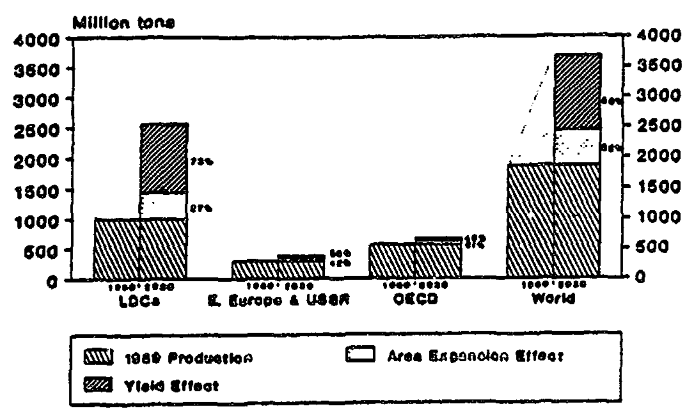
Source: World Bank data; D. Anderson 1992.

Grain Yields
1961 - 1989 and Prospective to 2030



Source: World Bank data, 1961 & 1970; FAO, 1989; D. Anderson, 2005 & 2030.

Yield and Area Expansion Effects
Prospective*: 1989 - 2030



Source: D. Anderson 1992.

marginal land -- hence current pressure on those good quality lands still remaining under forests.

Although such classifications are unavoidably crude, what is not in dispute is that, even outside arid zones, the combinations of soil and climatic conditions suitable for agriculture vary enormously. In the semiarid tropics of Africa and Latin America, three soil orders (Oxisols, Alfisols and Ultisols) respectively account for 46 percent and 47 percent of all soils. Stewart, Lal and El-Swaify (1991) describe these as "low-activity clay" soils, and Lal (1984, p. 76) says of such soils that they "exhibit little swell-shrink capacity. On drying, most of these soils become hard and have unusually high strength ...", which inhibits seedling emergence. Writing of tropical soils generally, Lal (1984, p. 77) notes that after a "relatively long period of natural or planted fallow" the organic matter content of the surface layer of these soils is comparable to that in temperate region soils. However, the organic matter in tropical soils typically is concentrated in the top 5 to 10cm. With land clearing, the soil organic matter is oxidized at a rate about 4 times faster than in temperate zone soils, and declines sharply in as little as 2 or 3 years. This is particularly significant for the low-activity clay soils, such as the Oxisols, Alfisols and Ultisols, because in these soils "... organic matter plays a very important role in improving structural stability, decreasing compactability, improving soil available water and nutrient resources, decreasing leaching losses, and enhancing biological activity of soil fauna (e.g., earthworms, etc.)" Lal (1984, pp. 77-8).

B. Geography, infrastructure and trade. Potentially available cropland is unevenly distributed among the developing countries; 45 percent is in Africa, and 50 percent in South America (see Table 19). There is little scope for area expansion in Asia. There is no reason in theory why the concentration of remaining uncultivated lands in Latin America and Africa, should be an obstacle to area expansion as a means of raising world agricultural output, since the better endowed countries could export to those less favorably endowed with potentially cultivable land. The expansion of world trade -- in agricultural as in non-agricultural products -- will clearly be crucial for alleviating pressures on land (and forest) resources. Nevertheless, it must also be associated with yield increases, not least in South America and Africa, given the significant costs of bringing additional land under cultivation in these regions.

Table 18 Land in various uses classified by potential for crop production, 1975 (million hectares)

	Land capability class for crop production				
	High	Medium	Low	Zero	Total
Cropland	400	500	600	0	1,500
Grassland	200	300	500	2,000	3,000
Sub-totals:	600	800	1,100	2,000	4,500
Forest land	100	300	400	3,300	4,100
Non-agricultural land	0	0	0	4,800	4,800
Totals	700	1,100	1,500	10,100	13,400

Table 19 Potential cropland (million ha)

	Potentially cultivable	Presently cultivated	Uncultivated	percent total
Africa	789	168	621	45
S.W. Asia	48	69	0	0
S.E. Asia	297	274	23	2
Central Asia	127	113	14	1
South America	819	124	695	50
Central America	75	36	39	3
	2,155	784	1,392	100

Source: Crosson and Anderson (1991), calculated from Buringh and Dudal (1987) Table 2.6, p22.

C. Pressures on forests, pastures and wildlife. Most new arable land in Africa and South America is obtained by clearing forests and woodlands; there is widespread intrusion on national parks and game reserves. The loss of wildlife and biodiversity associated with these changes (and perhaps also with changes in micro and regional climates brought about by deforestation), all entail economic costs that are not reflected in markets. Further, wildlife and forests in developing countries are increasingly valued as an international (as well as a national) public good for present and future generations for which no fully satisfactory international public financial arrangements have yet been made -- in contrast to national level arrangements in high income countries that provide for the protection and maintenance of parks, wildlife and architectural assets. Both public and private efforts to persuade governments to protect wildlife and forests in tropical areas have intensified in recent years, and if successful will reduce the rate of land clearance. In this case, the realizable cropland potential of South America, and possibly Africa, would be considerably less than the numbers in Table 19 suggest.

It is possible that some pasturelands could be converted to "settled" farming; but there are also economic limits to such conversion and, again, the over-riding evidence is that yield increases in arable areas already being farmed must be the main route towards relieving the pressure on forests and wildlife brought about by the growth of agriculture.[49]

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[49] On the limits to converting pasturelands, Stanford (1983,p3) notes with admirable clarity, that

> "Pastoralists in dry areas use their livestock to harvest and convert solar energy captured and fixed in plants into products useful to man. For in these regions it is generally impossible, or at least uneconomic, to convert it directly to man's use through the medium of grain, legume, and oil crops as is done in more fertile areas; and conversion through livestock allows a higher level of production and of human population than do the alternative techniques of hunters and gatherers. Plant growth requires adequate sunlight, soil

D. Disease as an obstacle. Diseases, affecting both humans and animals, inhibit the development of potential cropland in Africa and Latin America. Much of the discussion of this issue focuses on the tsetse fly, the major carrier of Trypanosomiasis, a serious disease affecting both animals and people, particularly, but not exclusively, in Africa.[50] In 1963, an FAO study of tsetse fly infestation in Africa estimated that some 10 million square kilometers of land in the central part of the continent were affected. A major consequence was a cattle population in the region far smaller than would have been the case in the absence of infestation. It also inhibits the conversion of land to crop production because much of African agriculture is dependent on an intimate relationship of animals and crops, with animals often providing the means of tilling the land. Although the tsetse infestation can be reduced by land clearance (it survives only in a forest environment) it has been noted that it is now mainly associated with marginal lands. Hence, the belief that much good land is available were it to be cleared of tsetse, is mistaken (Omerod 1986, p. 90).

E. Infrastructure. This is another source of rising costs in the opening up of new land to crop production. In both Africa and South America, the cost of building the transport and communication infrastructure necessary to move production inputs to the regions and take production out, has to be counted as part of the cost of realizing the cropland potential of the two regions.

3. Agricultural development and technical change

An analysis of food demand, the availability of land, and the costs of bringing new land under cultivation, points unequivocally to the necessity of yield increases. World annual grain requirements alone are likely to rise from around 1,700 million tonnes today to perhaps 2,000 million tonnes in 15 years' time, and 3,000 to 3,500 million tonnes in 40 years time (see Figure 16), with 90 percent of the growth arising from the growth of populations and per capita incomes in the developing countries. In addition, there will be commensurate increases in the demand for a variety of other crops, which currently occupy another 35 percent of croplands, and for fruit, meat and dairy, which have large, but inaccurately known, area requirements. It

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nutrients, and water; and while dry areas may have plenty of the first two, by definition they lack the last. Plant production expressed in terms of yields per hectare, therefore, is low. Pastoralists use their livestock to harvest and process these low yields into useful products more economically than can be done by hand or machine; and pastoral societies and systems of land-use are adaptations to local natural environments (and also to local political and economic conditions) whereby the yield of plant production can be exploited. Inheritance, marriage, and property laws regulate the combination of different species of livestock with water, land, labor, and other resources, and livestock and people move from place to place in such a way as to maintain the efficiency and security of the harvesters and processors and of the labor that tends them. This is not to claim that the actual social and land-use system in force in any pastoral situation is the only possible one or necessarily the best from all points of view; only that, unless it is a very recent arrival, or unless there has been some dramatic change in circumstance, it is at least not a chance freak of nature that any hasty and ill-thought change is as likely to improve on as to injure."

[50] In people the disease is commonly called sleeping sickness.

is unlikely that food needs can be met without the successful application of technical progress. (A scenario of yield increases and corresponding changes in land use is shown in Figures 16 and 17.)

A lack of technical progress and consequent agricultural yield increases, will result in poverty, malnutrition and famines on an unthinkable scale and, returning to the environmental concerns of this paper, in pressures on soils, water resources, forests and wildlife, of an order of magnitude greater than experienced in recent decades. Perhaps in no other area are the aims of poverty alleviation, environmental management and economic growth more congruent than in agricultural development.

The experience of agricultural development over the past forty years -- successful and otherwise -- shows there is still considerable scope for further output growth. The capacity of agricultural output to expand has been convincingly shown to be dependent not only on available land, but on agricultural technologies deployed and quality of land management. The period saw an unprecedented increase in world agricultural output accompanied by a massive expansion in the quantities of land devoted to agricultural production.

Moreover, the scope for further increases in the developing countries is considerable. In some developing countries, yields are already high; in China, Egypt and Korea, for example, grain yields are respectively around 4, 5.5 and 6 tonnes per hectare, comparable to yields in the United States, Denmark, Holland and Japan (see Table 20). By contrast, yields in most other countries fall in the range 1.5 to 2.5. In some countries, again in Africa and Latin America, the greater availability of land did not exert the same pressure for yield increases as it did in others; and, of course, a country's capacity to raise yields has to be assessed in relation to several other factors, including climate, water availability and the quality of soils. Nevertheless, the quality of natural resources alone cannot explain yield differentials between countries, and the assessment of most agriculturalists is that there remains a great deal of scope for yield increases in developing countries.[51]

Third, the output and yield increases obtained by developing countries over the period, were frequently achieved in the face of a huge and express economic policy bias against agriculture, as public and -- through various tax, credit and trade incentives -- private resources were massively diverted to urban-industrial expansion. With the notable exceptions of China and some other East Asian countries, agriculture performance has been poor in relation both to the growth of demand for agricultural products and to what was achievable. Although aggregate growth averaged 2.9 percent[52], this was only 0.4% percentage points higher than population growth - and was below population growth in several African countries and parts of Asia. Reviewing reasons for this, Hayami and Ruttan (1985, p416) conclude that "the basic factor

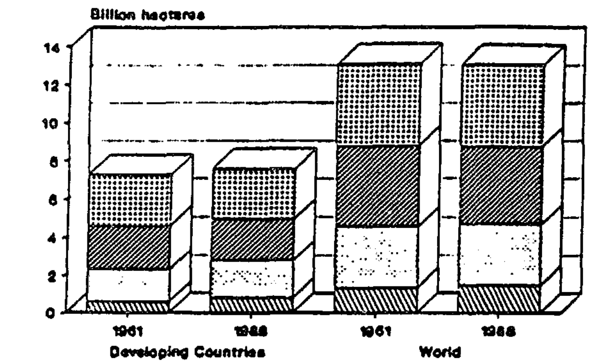
[51] Crosson and Anderson.

[52] 1982 Report. Figure to be updated.

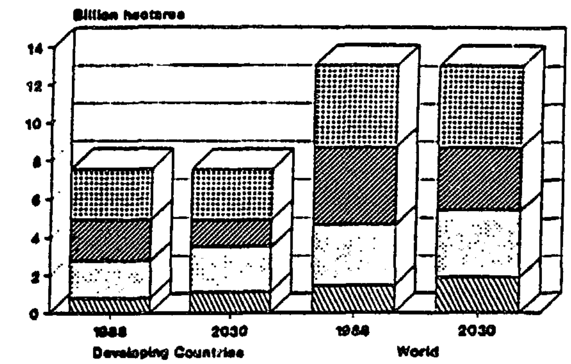
Figure 17 Land Use

Land Use

Actual: 1961 and 1988



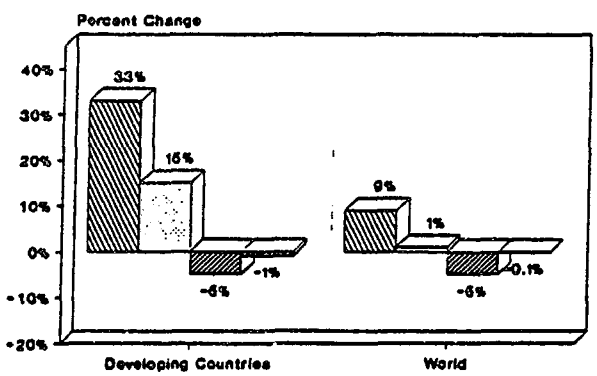
Prospective: 1988 to 2030



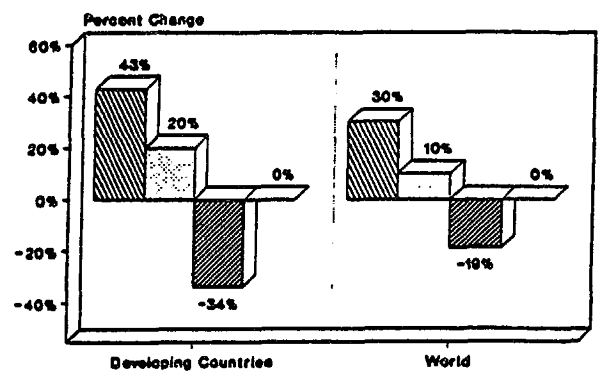
Sources: World Bank data, 1961; FAO, 1988; D. Anderson, 2030.

Land Use Percent Change

Actual: 1961 and 1988



Prospective: 1988 to 2030



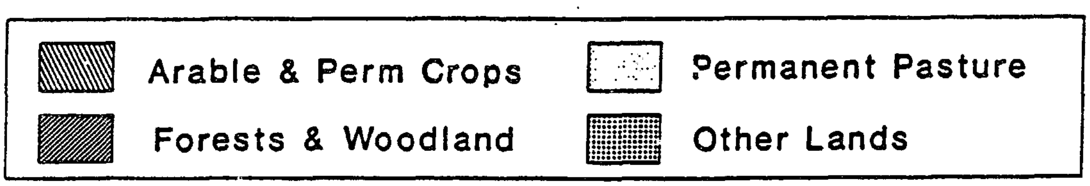


Table 20 Cereal yields by region and for selected countries, 1969-89

	(tons per hectare of harvested area)			% Change	Growth Rate (%)
	1969-71	1979-81	1989	1970 to 1989	1970 to 1989
Industrialized Countries					
United States	3.50	4.20	4.41	26.0	1.2
Denmark	3.85	4.02	5.60	45.5	2.C
Netherlands	4.02	5.69	6.76	68.2	2.8
Japan	5.04	5.27	5.67	12.5	0.6
Developing Countries					
Africa					
Burundi	1.04	0.99	1.49	43.3	1.9
Cameroon	0.89	0.89	1.05	18.0	0.9
Egypt	3.85	4.01	5.52	43.4	1.9
Kenya	1.47	1.50	1.75	19.0	0.9
Malawi	1.00	1.18	1.18	18.0	0.9
Zimbabwe	1.08	1.36	1.44	33.3	1.5
Tanzania	0.78	0.70	1.46	87.2	3.4
Zambia	0.76	0.74	1.94	155.3	5.1
Asia					
Bangladesh	1.66	1.96	2.45	47.6	2.1
Sri Lanka	2.40	2.42	2.56	6.7	0.3
India	1.11	1.34	1.85	66.7	2.7
Korea, Rep. of	3.50	4.77	5.98	70.9	2.9
Malaysia	2.39	2.82	2.65	10.9	0.5
Pakistan	1.21	1.61	1.77	46.3	2.0
Philippines	1.30	1.59	2.00	53.8	2.3
Thailand	2.01	1.94	2.12	5.5	0.3
China	2.38	3.03	4.01	68.5	2.8
Latin America					
Argentina	1.71	2.20	2.05	19.9	1.0
Brazil	1.33	1.50	2.00	50.4	2.2
Colombia	1.72	2.46	2.52	46.5	2.0
Chile	1.86	2.12	3.92	110.8	4.0
Costa Rica	1.55	2.25	2.60	67.7	2.8
Ecuador	1.04	1.61	1.76	69.2	2.8
El Salvador	1.57	1.72	1.93	22.9	1.1
Guatemala	1.12	1.51	2.10	87.5	3.4
Mexico	1.52	2.11	2.14	40.8	1.8
USSR	1.48	1.41	1.91	29.1	1.4
Eastern Europe	2.46	3.20	3.80	54.5	2.3
Developing M.E. (excl. China)	1.24	1.50	1.84	48.4	2.1
Developed M.E.	2.88	3.44	3.80	31.9	1.5

Source: FAO Production Yearbook, 1980, 1989.

underlying poor performance was neither the meager endowment of natural resources nor the lack of technological potential to increase output from the available resources at a sufficiently rapid pace to meet the growth of demand. The major constraint limiting agricultural development was identified as the policies that impeded rather than induced appropriate technical and institutional innovations. As a result, the gap widened between the potential and the actual productive capacities of LDC agriculture."

The implication is that policies designed to broaden the basis of agricultural development would meet with a response from farmers, thus raising yields and output. The key elements of such policies have been reviewed in many studies and can be briefly stated: openness to trade, a more neutral system of tax and related incentives between agriculture and industry, a greater reliance on markets and less on parastatals (for marketing in particular), tenurial reform, the provision of supporting social and economic infrastructure, and of course the further development of agricultural research and extension services. It has also been found that, paradoxically, such policies would <u>increase</u> the rate of industrialization, since they would help to relieve the food constraint on urban-industrial expansion and, by increasing incomes in rural areas, stimulate demand for non-food goods and services.[53] It is not co-incidental that off-farm employment opportunities rise (and thus pressures to farm marginal lands decline) in regions where agricultural development, broadly defined, is successfully taking place.[54]

4. Soil management and conservation

Satisfactory evidence on the extent of land degradation and its consequences for land productivity are not available for developing countries. The most widely quoted study is a survey undertaken by UNEP (1984) which found "threatened areas" amounting to 4.5 billion hectares, or 35 percent of the land surface of the earth. However, these surveys rely on the judgements of government staff completing questionnaires, not on field measurements, and the results are consequently controversial.[55] There is much disagreement among scientists and others as to the extent and causes of soil erosion and degradation in developing countries, and it is unlikely to be resolved until satisfactory monitoring and research facilities are in place. Nevertheless, there are numerous field reports of soil degradation in particular locations, and there is widely-felt concern about its consequences for the sustainability of agricultural systems.

Uncertainties in the evidence notwithstanding, there are some areas of agreement:

(1) Where degradation is occurring, soil management and conservation practices are available to avoid it, and may even enhance the productivity of soils. Indeed,

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[53] Johnson and Kilby (1976), Liedholm (1980) and World Bank (1978).

[54] Ibid.

[55] See Bojo (1991) and Nelson (1990).

they are often adopted because it is in the farmers' interests to do so, and in this sense are "proven" practices.

(2) Such practices show good economic returns, and the encouragement of their wider adoption does not need to be justified by reference to scenarios of ecological catastrophe. They are good husbandry, and a means of improving yields.

(3) They are more likely to be adopted when tenurial and economic incentives favor them, and when there is supporting public investment in rural infrastructure, education, training, research and extension services. Not coincidentally, such policies also favor the growth of agriculture.

(4) Given the limits to land availability discussed above, and the importance of raising yields, the adoption of good soil management practices in developing countries assumes greater rather than lesser importance over time.

(5) The greater fragility of soils in developing countries, provides a further argument for the adoption of good soil management practices.

The practices in question vary greatly in approach, cost and effectiveness, and agronomists counsel against looking for a single solution to a given problem. Practices can be grouped into what are termed structural practices, and practices involving changes in the use of vegetation and methods of cultivation. The former are generally used in watersheds, and may involve the construction of earth banks and bench terracing or the levelling of land. Costs can be high. MaGrath and Doolette (1990) note that costs "for terracing in Indonesia are estimated to range from $400 to $1,000/hectare. Construction of earth bunds in India is estimated to cost between $23 and $150/hectare depending on soil type and slope. Aside from high initial costs and the financing burden they impose, structural techniques inevitably require high levels of maintenance. Failure to maintain structures properly can lead to their total failure and can actually accelerate soil loss." Nevertheless, bench terraces are in place over vast areas for rice paddy and in arid regions to harvest rainfall on slopes.

Changes in uses of vegetation and methods of cultivation to conserve soils take many forms, and are effectively applied on slopes and plains. They are a much lower cost option than structural measures. They include:[56]

(i) Use of grass cover and strips (reductions of runoff ranging from 56 percent to 90 percent have been observed on slopes from 0.5 percent to 46 percent when compared to surface runoff from other practices);

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[56] See Doolette and Smythe (1991).

Box 10 Vetiver grass - contour system for soil and moisture conservation

The notion of carrying out all farming operations especially cultivation and planting on the contour in any rainfed situation, on any slope, for any crop is overwhelming. Customarily, barriers are constructed on the contour at certain vertical intervals according to slope to break the length of the slope so as to check the velocity of runoff water and trap silt. These also serve as guidelines for contour cultivation. Graded earth banks (bunds) usually with a horizontal gradient of up to 1 percent to feed excess water into a prepared waterway have been employed extensively. These structures have severe limitation in the tropics and do not fit small holdings due to loss of arable area for the bank itself and the waterway.

Vegetative barriers on the contour have distinct advantages over earth banks: they require about one-tenth of the space and no water disposal system is necessary; they slow down surface runoff and cause it to deposit the silt load; the water that seeps through spreads out, with increased opportunity to infiltrate. This also avoids the problem of waterlogging which is common behind the bank.

A plant suitable for a vegetative barrier requires particular morphological characteristics. Its root system should be aggressive and deep without rhizomes or stolons so as not to spread out of line; the crown should be below the surface for protection against fire and overgrazing; the culms tough and unattractive to animals and pests; and the flowers, if any, essentially sterile so as not to permit spreading by seed. The plant should be a perennial and persistent, tiller freely and intermingle with its neighbors (some clump grasses do not). To date, the only plant known to meet these criteria is vetiver grass, (Vetiveria zizanioides). It has an extremely wide range of climatic conditions over which it is adapted and further exhibits adequate growth over a wide range of soil types, including those with highly unfavorable properties for many plants. Vetiver grass has been used for this purpose and as permanent field boundaries for a long time, and hence it is known to persist, once established, without maintenance indefinitely. It is propagated by root slips which the farmer may plant himself on a roughly surveyed contour lines. Given moderately favorable conditions, the hedge would be complete after three growing seasons, fewer with high fertility, high rainfall and close planting.

Apart from physical advantages, establishing and maintaining the system is low-cost and can be carried out entirely by the farmer. Compare this with the engineered system which requires earth-moving equipment, complete cooperation among neighbors especially for water disposal components that may impose an intolerable burden on those further down the slope, and regular rebuilding every three to five years.

Vetiver grass has other applications due to its unique morphology. Among these are protecting paddy banks, dam catchments and drainage lines from siltation, roadsides and stream banks from erosion, and performing the soil-and moisture-conservation function when planted in V-ditches with fruit and forest trees.

The same technology can be used for the stabilization of degraded nonarable lands. Vetiver grass can be used, but in these nonarable situations, shrubs that can be coppiced for fuel or fodder could also be used as barriers on the contour. The search for suitable shrubs continues.

Source: Magrath and Doolette, 1990.

(ii) Mulching, which protects the soil from raindrop impact, reduces evaporation from the soil surface, and slows down runoff, giving more time for water to infiltrate. Significant effects on farm yields have been reported;[57]

(iii) Contour cultivation; reports from India suggest that this practice alone reduces surface runoff by 25 percent when compared to up-and-down slope cultivation; larger effects have been found in other studies, particularly when combined with mulching;

(iv) Ridge and furrow; ridged and furrowed plots have demonstrated deeper percolation of water, with increases of 120 percent in soil moisture storage and decreases in surface run-off;

(v) Use of plants such as vetiver grasses to form physical barriers to slow run-off, arrest erosion and improve moisture retention (see Box 10);

(vi) Agro-forestry (sometimes called social- or farm-forestry).[58] This involves a greater use of trees (for example, on farm boundaries) in the farming system; it improves soil moisture levels, nutrients and structure, and provides by-products such as wood for fencing and building, fodder, fuel, fruit and shade for livestock (see Figure 18).

In a review of over 220 field measurements and experiments in 40 countries, covering all regions of the world, Doolette and MaGrath found that such practices, when applied reasonably, were capable of reducing erosion to negligible levels and improving soil moisture and fertility. The actual impact on crop yields varied greatly, from small in some cases, to 200 to 300 percent in others; the average was 30 - 50 percent.[59] Given low introduction costs, there were very high rates of return to the investment of time, labor and materials involved. The results show unambiguously that good soil management and conservation practices are not only environmentally desirable, but a means of raising yields and aggregate output in agriculture.

VII. COMMON THREADS

Interactions between economic activities and the environment differ greatly from one sector to another. However, as the preceeding analysis shows, there are several threads running through all areas of concern. These relate to the growth of populations and per capita incomes (and the consequent demands placed on productive activity), to poverty alleviation, to macro-

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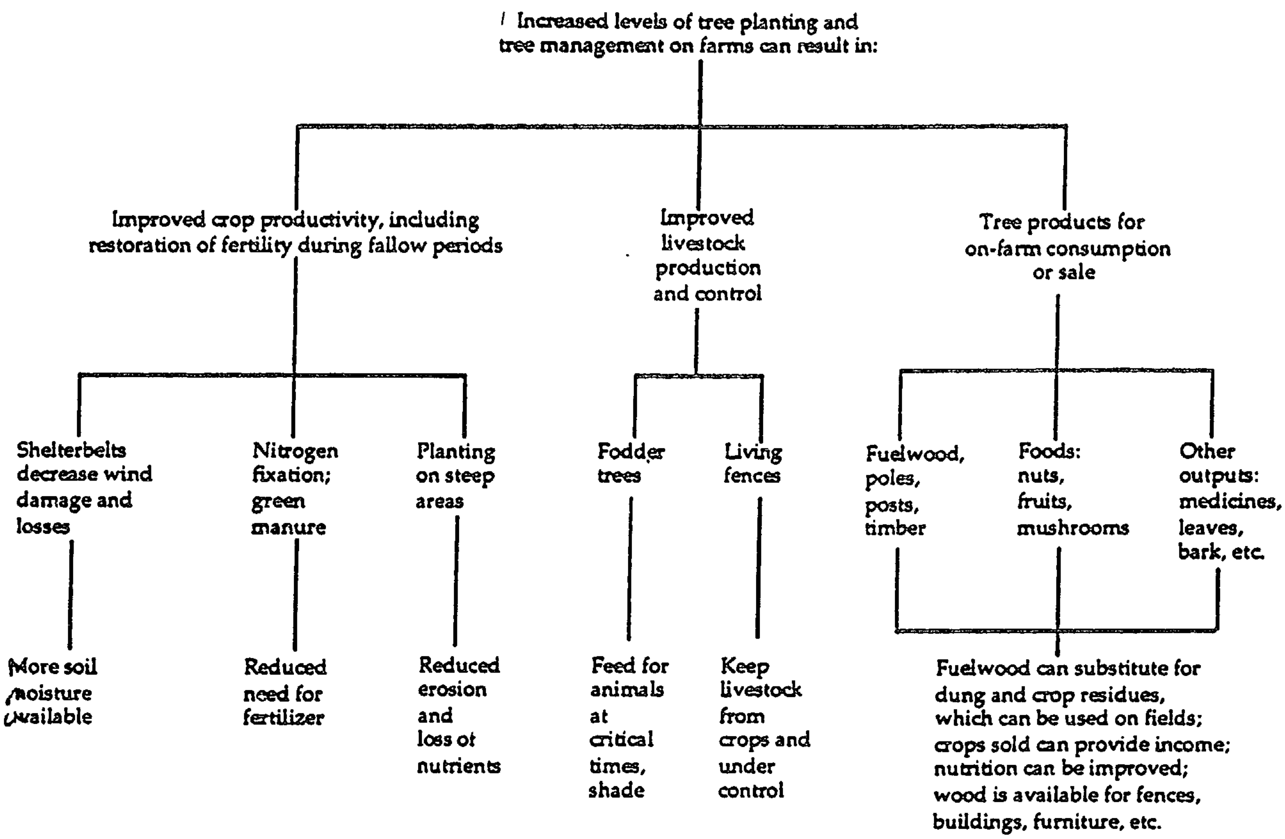
[57] Ibid.

[58] See Gregerson, Draper and Elz (1989).

[59] op.cit. Table 8.4.

economic stability and trade, and to the environmental (and of course economic) importance of efficiency in resource use.

Figure 18 On-farm benefits from trees in the farming system



Source: Gregerson, Draper and Elz (1989).

1. The growth of populations and per capita incomes

Behind the growth in demand for the services and products discussed above -- water and sanitation, commercial energy and transport, industrial and agricultural products -- were two strong driving forces. One was the growth of populations in developing countries; the other, the growth of per capita incomes in both developing and industrial countries.

Between 1960 and 1990, the world's population rose from 2.9 to 5.3 billion. Allowing for changes in fertility rates and life expectancy as living standards improve, and for some successes with family planning programs, the world's population will probably rise to over 8

billion by 2030 and to over 10 billion by 2050, when -- on current expectations -- it will be approaching its peak. Ninety-five percent of this growth is likely to occur in developing countries. Other things being constant, therefore, population growth alone will account in the coming decades for more than a doubling of demand for the products and services discussed above.
&2

The growth of per capita incomes in developing countries, combined with high income elasticities, exerts even stronger demand effects than population growth. Even if population growth were to be lower than conservative projections suggest, the expansion of demand for the products and services in question would still be very large. For commercial energy, transport services and industrial products, per capita income elasticities in developing countries are all greater than one; for electricity and some industrial products they are as high as 2, and for agricultural products they are around half, depending on income levels and the product in question. These are uniformly higher than in industrial market economies where, with familiar exceptions (for example, in electronics products), markets are "saturated" or "mature", and the main source of growth is in product service and quality (including environmental quality) rather than quantitative expansion.

But in the developing countries, including the newly industrializing countries in East Asia, per capita consumption levels are still relatively low, and for many decades the scope for catch-up will be enormous, as the consumption data discussed earlier showed; for instance, commercial energy consumption in Africa and South Asia is only 3 percent of that of the US, and only 8 percent that of Europe and Japan, and in East Asia (including or excluding China) only 8 percent of the American figure. For these reasons developing country per capita income growth in the next two decades will alone more than double demand for the products and services discussed above, and more than triple demand in East Asia. Although such expansion is substantial, it is not so large as to be unattainable; allowing for economic recovery in Africa and Latin America and for the maintenance of growth in Asia, per capita income growth rates in the developing countries would have to average 3 percent to achieve the necessary levels of income and output. Income levels will still be very low compared to those in the industrial countries.

Three conclusions follow from these considerations and the analysis presented so far. First, the idea of reducing per capita GNP and its growth in order to address environmental problems is non-operational. If implemented, it would further impoverish millions of people in developing countries and, as discussed above with reference to water and sanitation in urban areas, and to agricultural development, greatly intensify environmental problems. There is of course scope for increasing utilities derived from income growth: through reducing unnecessary waste, wastage of water, urban congestion; through improving energy efficiency; and by shifting to lower waste and emission options in industrial production. But these and other measures would increase, not reduce, per capita GNP because they are associated with economic efficiency and because they raise economic returns to investment.

Second, the most effective approach to reducing environmental damage from economic activities and their expansion, is to address it directly -- to "delink" it from economic activities, so to speak -- by introducing environmentally superior technologies and practices. Such options are either available, emerging or capable of development in all spheres of economic activity -- energy, water supply and sanitation, transport, industry, and agriculture -- and may reduce environmental damage and its costs dramatically as economic output expands after their incorporation into the economic system. As with various measures for reducing waste and improving efficiency, the paradox is that, provided environmental policies are introduced in an economically desirable way, their effect is to raise economic output still further -- for example, by raising the productivity of agriculture and the health of people. Except when a country is already at the margins of environmental policies, the costs of the various types of investments and managerial practices discussed are not large in relation to their benefits. They are also low in relation to the costs of the much-discussed sources of economic inefficiency associated with environmental damage; for instance, the costs of energy inefficiency, of urban congestion, or of water waste. The implication is that, the benefits of removing such inefficiencies would more than offset the extra costs of environmental policies -- even ignoring the benefits of the latter. Overall, the possibilities for reducing pollution in urban areas and alleviating environmental pressures in rural areas are appreciable in developing countries.

Third, reducing population growth, as many have argued, would help to relieve environmental pressures in urban and rural areas. However, from an environmental perspective these effects would be small in relation to the two measures discussed above -- reducing waste and inefficiency, and introducing environmentally superior technologies and practices. A 10 or even 20 percent reduction in long term population relative to currently projected levels would reduce emissions by only 10 or 20 percent; overall, emissions and wastes would still be appreciably larger than they are today. Population growth thus increases the environmental and economic case for more widespread use of the various low polluting options discussed above. Similarly, in rural areas, reductions in soil degradation must rely more on good husbandry and greater yields than on population control. Nevertheless, reducing population growth would help to alleviate pressures on agriculture, land and natural resources.[60]

2. Poverty, growth, and the environment

The 1990 World Development Report (on Poverty) concludes that rapid and sustained progress on the reduction of poverty requires policies with two equally important elements. The first is "to promote the productive use of the poor's most abundant asset--labor." It calls for policies that harness market incentives, social and political institutions, infrastructure and technology to that end. The second is "to provide basic social services to the poor. Primary health care, family planning, nutrition, and education are especially important." Poverty reduction through such policies is seen to be a means of improving the efficiency with which resources (most of all human and capital resources) are used, and thus a means of raising

[60] Population policies were surveyed by the Bank in the 1984 World Development Report, and revisited in the 1991 Report.

economic growth; as, indeed, layer-upon-layer of economic research has found over the past four decades -- on employment, on human resources, on agrarian reform and agricultural development, and on trade and industry.[61]

Addressing environmental problems efficiently is fully consistent with poverty alleviation, and is an aspect of the policies required to achieve it:

Health. The evidence that pollution has a disproportionately higher impact on low income groups is overwhelming. The incidence of water borne illnesses among the poor is very high, as is their exposure to indoor and outdoor air pollution. The adverse effects of pollution on health may be compounded because of poor nutrition, bad housing conditions and poor access to health services.

Productivity. Aside from losses to human welfare, ill-health arising from pollution was also seen to lower income and thus incur economic costs. But the effects on productivity extend beyond those related to ill-health. They include the costs and inefficiencies of fetching and carrying water when public supplies are not available (Box 3 above); the increasing amounts of time and labor required in collecting fuelwood as this resource becomes scarce (Box 12); and in many regions the reduced productivity of natural resources, for instance the degradation of soils arising from the use of wood and dung as fuels, and the destruction of inland and coastal fisheries by industrial water pollution and municipal sewerage.

Broadly based agricultural development. This is another area where the policies required for poverty alleviation, growth, and addressing environmental concerns are fully congruent. The various policies to reduce poverty in rural areas and raise agricultural output have been reviewed in several studies.[62] Here, it is sufficient to recall four key elements:

- The adoption of a system of economic incentives that is neutral between agriculture and industry. The historical bias in credit, tax, and trade policies towards industry in many countries has long been shown to raise capital intensity, reduce labor demand and reduce the economic rate of return to investment.[63] More neutral incentives would raise the efficiency of investment and the demand for -- and productivity of -- labor. It would also improve incentives for raising output and yields in agriculture and, as noted earlier, stimulate the growth of non-farm employment and earnings opportunities in rural areas (again reducing pressure on land resources).
- Tenurial reform. This would raise the demand for and productivity of labor in rural areas, and also agricultural yields and output.

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[61] This theme was developed further in the 1991 WDR.

[62] WDR 1990 provides one recent survey.

[63] The classic study is still Little, Sckitovsky, and Scott (1969).

Box 12 Pollution and labor productivity: the case of firewood

Firewood is not only a highly polluting fuel, and its collection a source of environment damage, but (as in the fetching and carrying of water), the time spent collecting it takes away from other productive activities.

Conclusive demonstration of this link comes from a study of household time use in hill areas of Nepal (Kumar and Hotchkiss, 1988). In villages with severe deforestation, women were spending over an hour more than women in less deforested areas collected fuel wood. Considering collection time for other forest products, the total effect on labor available for agriculture was estimated to be as much as one and a half hours a day taken away for collection activities. With labor relatively scarce, the potential loss of household labor from agricultural activities was 24 percent. Further, it was shown that families were not able to compensate for this diversion of labor, resulting in a reduction in household income from agriculture, and a deterioration in food consumption levels and nutritional status.

Different versions of this Nepalese story are told for many parts of the developing world, but few are so completely documented, and care must be taken in generalizing it. It is well established that women and children are most often the collectors of fuel wood, and that the additional collection burden resulting from forest cover degradation falls most directly on them. Time devoted and distance travelled for collection vary widely, but in many places are already substantial, ranging up to four to five hours/day and as much as 10 kms. (Agarwal, 1985; Barnes, 1990). What is generally lacking is information on how collection time and distance has changed in association with deforestation. Increasing woodfuel scarcity does not appear to lead to constantly growing time allocations for collection; once local scarcity constrains free collection by individuals, alternative collection strategies emerge. Local organization of transport for more distant collection may arise and foster informal markets, such that the impact on poor rural families comes through budget costs rather than through labor requirements.

- The provision of supporting social and economic infrastructural services in rural areas.
- Developing extension services, with the extension message being broadened to address issues in soil management and conservation, and rural ecology.

Employment. Economic activities stimulated by environmental policy are often labor intensive (as well as economically productive), and are thus a means of raising real incomes and wages in low-income regions. Examples include the establishment of agro- or farm-forestry practices on farmlands and watersheds; the planting of windbreaks or shelterbelts, and the extraction of timber from them, in areas threatened by erosion and desertification; soil erosion control programs in general; the protection and maintenance of wildlife and forest reserves; and the construction and maintenance of water supply, sewerage, storm drainage, and solid waste disposal systems.

Nevertheless, there are cases, such as coal, where environmental policies have been questioned on the grounds that they cause unemployment. Two observations may be made here. First, where emission control or lower waste technologies are introduced the effect is often to maintain an industry's growth by delinking pollution from output, as discussed earlier. Second, where the effect is to reduce an industry's output, for example, where gas or renewable forms of energy are substituted for coal, the problem in hand is one of the redeployment -- and not the long-term unemployment -- of labor, an issue of macroeconomic management. Alternative employment opportunities will emerge either in competitor industries, such as gas or renewables, and their supplier and contractor industries, or in industry in general, as capital (like labor) is redeployed to other ends. In the past, economies have seen massive redeployments of labor (and continue to do so) in the course of economic growth, most notably from agriculture to industry, from coal to other industries, from small-scale to large-scale manufacturing, from heavy to light ("high-tech") industries, and so forth; redeployment between economic activities is a force for social change and growth and not in and of itself a source of long-term unemployment. Where redeployments of labor emerge from environmental policies, therefore, this does not raise insurmountable problems of economic management.

We should thus conclude, along with the Brundtland Report, that the aim of reducing poverty in the course of economic growth is fully consistent with the aims of addressing environmental problems efficiently, and vice versa.

3. Macroeconomic stability and trade

Another common thread is that macroeconomic stability and the growth of world trade are both necessary conditions for bringing about environmental improvements. Neither are sufficient conditions, since if microeconomic policies, laws, and public institutions neglect, or (worse) encourage pollution and environmental damage, economic growth and trade may -- and, in notable cases does -- intensify environmental damage. But it is equally true that if microeconomic policies, laws, and institutions seek environmental improvements, they are unlikely to be effective if an economy is unstable or where there are significant barriers to trade. In environmental matters as in other aspects of development, success depends on several factors working together and not in opposition.

The key points about the importance of macroeconomic stability --that it fosters confidence in the future, clarifies price signals, and raises resources -- were raised earlier and are self-evident.[64] Countries prone to inflation and instability, invariably have distressed budgetary situations, reduced savings rates, lower rates of profit, and blurred pricing signals, all of which undermine investment and maintenance activities in environmental (as in most other) areas. People in both government and nongovernment activities, and in their private and working lives become preoccupied with the short term. Lastly, inflation worsens the distribution of income, undermining poverty reduction programs, and increasing (it may be inferred) pressures on environmental resources in urban and rural areas.

The growth of world trade can also be a source of environmental damage if, by neglect

[64] Its quantitative importance for raising resources (not only for environmental ends) was discussed in the 1991 World Development Report.

or intent, local policies are directed to that end -- as with many logging operations in the tropics and elsewhere, or with the encouragement of investment in industry in the absence of pollution controls. But to sacrifice trade (or macroeconomic stability) with the aim of reducing environmental damage would necessarily be self-defeating; the best -- and, arguably, the only operational -- approach is to address environmental problems directly, and use trade (and macroeconomic stability) to help achieve environmental improvements. If this approach is followed, there are two respects in which the growth of trade may contribute to environment and development; one indirect, the other direct. The indirect contribution is via its contribution to economic growth, and thus to the finance of environmentally desirable activities, such as water and sanitation, "clean" energy technologies, agricultural R&D, related human resource development initiatives, and so forth.

The direct contribution is perhaps most vividly illustrated by the growth of agriculture and the associated problem of meeting the world's future food needs. From both agronomic and economic perspectives the world's agricultural system does seem to have the capacity, and the land base, to meet future food demands -- at least over the next forty to fifty years. The technological potential is far from being fully exploited and, in much of the developing world, impressive gains have been made since the 1950s despite domestic policies that were frequently biased against agricultural development; these difficulties were further compounded by agricultural protectionism in OECD countries. More favorable policies towards agricultural development and trade would stimulate further growth from both existing and new technologies.

Nevertheless, an immense effort will be required to raise yields in line with the productivity achievements of the past three decades. As discussed earlier, the possibilities for area expansion are becoming more limited and costly. Some regions will be better placed than others to raise output because yields are still low and there is more scope for technological catchup and area-expansion (Latin America, Africa, Eastern Europe and the former Soviet Republics), or because of more favourable land endowments (North America, Latin America and the former Soviet Republics). Comparative cost advantages in agriculture are likely to shift appreciably as food demands rise and the opportunities for achieving further output gains change over time. With regard to the growth of world trade in agricultural products, three conclusions follow:

- the growth of such trade will become increasingly important for meeting world food demands as populations and per capita incomes grow in the developing countries;
- it will also be a means of relieving environmental pressures on marginal lands (and also on forests and wildlife) if the export potential of those countries with good yields and outputs is permitted to develop;
- parallel growth of trade and foreign direct investment in industry would also need to occur (in exchange for agricultural products).

In summary, the growth of trade in agricultural and industrial products is likely to become even more important than it has in the past for meeting world food needs - and also for relieving environmental pressures in rural areas.

4. Efficiency

The environmental benefits of seeking economically more efficient uses of resources are another common thread Such benefits are most frequently noted under the heading "energy efficiency." But the possibilities are much wider than this and extend to all the sectors of economic activity discussed above, namely:

- to water and sanitation, where a wider adoption of cost-reflecting prices and managerial improvements would reduce costs (by reducing water wastes) and facilitate expansion of services;
- to all forms of energy production and use, where again the scope for improvement in the efficiency of prices, and of managerial and technical efficiency, is appreciable;
- to urban congestion, where congestion pricing and the various means of improving transport and pedestrian facilities would reduce pollution, improve amenity and raise the productivity of urban areas;
- to agriculture, where historical biases in development policy have often worked against efficiency improvements and good husbandry;
- and to industry, where again approaches such as in-plant recycling and low waste practices have led to significant economic developments.

These are all possible sources of economic improvement -- even if the economic and welfare gains from the environmental improvements they bring about were not counted. However, economically efficient policies aim first at realizing these gains and then go further by striving to allow for the external costs of environmental damage. When implemented, they may bring about fundamental improvements in both the physical environment and economic performance.

Statistical Annex Table 1 Air pollution in selected cities

		Sulphur dioxide No. of days over 150 ug/cubic meter				Suspended particulate matter: No. of days over 230 ug/cubic meter			
	City	Site Years	Min.	Aug.	Max.	Site Years	Min.	Aug.	Max
China	Beijing	8	0	68	157	8	145	272	338
	Guangzhou	12	0	30	74	10	7	123	283
	Shanghai	10	0	16	32	10	19	133	277
	Shenyang	7	43	146	236	13	117	219	347
	Xian	7	4	71	114	10	189	273	327
India	Bombay	13	0	3	32	12	23	100	207
	Calcutta	8	0	25	85	8	189	268	330
	Delhi	12	0	6	49	12	212	294	338
Indonesia	Jakarta	-	-	-	-	7	4	173	268
Iran	Tehran	15	6	104	163	15	8	174	347
Malaysia	Kuala Lumpur	1	0	0	0	5	10	37	59
Philippines	Manila	4	3	24	60	7	0	14	225
Korea	Seoul	6	5	87	121				
Thailand	Bangkok	3	0	0	0	12	5	97	209
Chile	Santiago	9	0	19	55				
Brazil	Sao Paulo	11	0	12	32				
Poland	Warsaw	13	3	10	19				
	Wroclaw	15	1	3	22				
Yugoslavia	Zagieb	15	3	30	80	15	13	34	57
Europe	Brussels	13	0	12	32				
	Copenhagen	3	0	0	0	6	0	0	1
	Frankfurt	6	8	20	38	3	0	0	0
	Munich	3	0	0	1				
	Gourdon	4	27	46	64				
	London	6	0	7	17				
	Lisbon					7	4	12	28
USA	Chicago	4	0	1	2	7	0	6	14
	New York	12	1	8	22	12	0	0	0

Source: Taken from Table 24.5 of World Resources 1990-91, World Resources Institute. Oxford: OUP, based on data from the Global Environmental Monitoring System (GEMS) data.

Statistical Annex Table 2: Origins of sulphur deposition in Europe

Receivers		CS	FR	DD	DE	BL	HU	IT	PL	ES	SC	SU	GB	OE	UI	Sum
		Emitters														
Czechoslovakia	CS	385	11	128	28	5	45	10	95	1	0	2	7	13	28	765
France	FR	19	332	41	40	28	5	21	15	65	0	0	43	8	140	760
GDR	DD	84	14	725	61	11	2	2	32	1	0	1	15	3	24	976
West Germany	DE	47	69	163	330	44	3	13	23	6	0	1	45	6	64	821
Benelux	BL	4	32	15	51	102	0	0	4	2	0	0	31	0	19	267
Hungary	HU	31	3	16	6	1	190	12	25	0	0	1	1	28	18	337
Italy	IT	13	21	15	8	2	11	353	14	10	0	1	4	19	86	562
Poland	PL	145	15	310	47	10	40	10	790	1	1	18	15	21	64	1492
Spain	ES	2	11	5	3	1	2	2	3	523	0	0	6	16	98	674
Scandinavia	SC	17	5	48	18	6	4	2	44	0	59	33	32	30	194	501
Soviet Union*	SU	107	10	167	36	8	84	13	337	1	8	2204	16	97	491	3584
Britain	GB	5	14	15	11	8	0	1	3	2	0	1	571	6	60	702
Other Europe	OE	95	40	97	49	8	141	136	101	29	3	95	70	825	435	2163
N Africa	NA	105	136	253	131	71	64	182	194	210	28	196	437	254	821	3087
Sum		1064	721	2005	823	322	594	759	1685	856	107	2558	1271	1377	2553	16695
Error		5	8	7	4	17	3	2	5	5	8	5	-22	51	11	1

Note: Sulphur dioxide figures will be about twice as large. Total wet plus dry deposition of sulphur for period 11.12.87 to 6.11.88, sums may not add to rounding errors (shown).

* Norway plus Sweden

** European part of USSR within EMEP area of calculation

*** Deposition in North Africa within areas of calculation

UI = unattributable to any country, plus small amount from NA

Source: Acid Magazine Sep 1989, from EMEP data. Quoted from Newbery (1990)

Annex Table 3 - Health effects of pollutants from motor vehicles

Pollutant	Health Effects
Carbon monoxide	Interferes with absorption of oxygen by hemoglobin (red blood cells); impairs perception and thinking, slows reflexes, causes drowsiness, brings on angina, and can cause unconsciousness and death; it affects fetal growth in pregnant women and tissue development of young children. It has a synergistic action with other pollutants to promote morbidity in people with respiratory or circulatory problems; it is associated with less worker productivity and general discomfort.
Nitrogen oxides	Can increase susceptibility to viral infections such as influenza; irritate the lungs and cause oedema, bronchitis and pneumonia; and result in increased sensitivity to dust and pollen in asthmatics. Most serious health effects are in combination with other air pollutants.
Hydrocarbons	Low-molecular weight compounds cause unpleasant effects such as eye irritation, coughing and sneezing, drowsiness and symptoms akin to drunkenness; heavy-molecular weight compounds may have carcinogenic or mutagenic effects. Some hydrocarbons have a close affinity for diesel particulates and may contribute to lung disease.
Ozone	Irritates mucous membranes of respiratory system causing
(Precursors: HC and NO_x)	Coughing, choking, and impaired lung function; causes eye irritation, headaches and physical discomfort; reduces resistance to colds and pneumonia; can aggravate chronic heart disease, asthma, bronchitis, and emphysema.
Lead	Affects circulatory, reproductive, nervous, and kidney systems;
causing suspected	of hyperactivity and lowered learning ability in children; hazardous even after exposure ends. Lead is ingested through the lungs and the gastrointestinal tract.
Sulfur dioxide	A harsh irritant, exacerbates asthma, bronchitis and emphysema; causes coughing and impaired lung functions.
Particulate matter	Irritates mucous membrances and may initiate a variety of respiratory diseases; fine particles may cause lung cancer and exacerbate morbidity and mortality from respiratory dysfunctions. A strong correlation exists between suspended particulates and infant mortality in urban areas. Suspended particulates have the ability to adhere to carcinogens emitted by motor vehicles.
Toxic substances	Suspected of causing cancer, reproductive problems, and birth defects. Benzene and asbestos are known carcinogens linked to leukemia and lung cancer; aldehydes and ketones irritate the eyes, cause short-term respiratory and skin irritation and may be carcinogenic.

Note: There is growing evidence that the synergistic effects of these pollutants in combination may be far more serious than the adverse effects of individual pollutants. This is particularly the case where NO_x and SO_x coexist or occur in association with particulate matter.

Source: OECD [1988a], French [1990], ECMT [1990], Walsh [1989c]

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